

Research at the PS

Two articles bringing out some of the highlights of the particle physics research carried out at the proton synchrotron during the past ten years. The articles divide between the two techniques — 'electronics' experiments involving the use of counters and spark chambers, and bubble chamber experiments involving the use of hydrogen and heavy liquid bubble chambers.

1. Electronics experiments

G. Cocconi

During the past ten years, a good fraction of the research at CERN has centred on the use of the proton synchrotron. The nature and the quality of this research are so intimately connected with the possibilities offered by the accelerator, that, in tracing the history of this period, it is not clear whether the main responsibility for the achievements (and even for the few failures) rests with the physicists who performed the experiments or with the engineers who operated the accelerator and organized the experimental halls.

As a physicist who spent most of this time around the PS, I will present my recollections and my appreciation of the research with the so-called 'electronics' techniques, i.e. with apparatus incorporating detectors giving electronic responses, such as scintillation counters, Cherenkov counters, and spark chambers.

At the beginning of 1960, when 25 GeV protons first started to hit the PS internal targets regularly, the relatively small group of physicists present at CERN was not really ready for experimenting with the various possible beams of secondary particles. Though this is a situation that easily arises whenever a facility far superior to the already existing ones enters into operation, in 1960 our preparation was abnormally poor: in post-war Europe there was no tradition of high energy research, and in CERN (only a few years old) most of the activity had been devoted to the construction of the accelerator itself. In 1960, the secondary beams were analyzed using a total of only three small bending magnets (borrowed from the 600 MeV synchro-cyclotron) and with no quadrupoles. Only at the beginning of 1961 did the first standard 1 and 2 m bending magnets arrive, and also some quadrupoles, and by the end of that year we could count on 20 units (now we have about 400 units). Fortunately, good electronics, with resolving times in the nanosecond range, was available in situ, thanks to the research which

had been in progress for some years at the synchro-cyclotron. Also, the analysis of the secondary beams was facilitated by the availability of a differential Cherenkov counter that a group in CERN had built and studied in advance.

This slow start explains why the first results were rather modest, and gives more meaning to the present flourishing status of European high energy research. Although it would be interesting to follow, year by year, the chronicle of all experimental achievements, I will select only a few lines of research that have flourished at the PS.

As a first example I will take the series of 'missing-mass' measurements. In a collision between two particles, the detailed measurement of the momentum spectrum of one of the particles emerging from the interaction gives valuable information about the mass of the 'missing' body formed by all the other particles produced. Measurements of this kind in proton-proton collisions were started at the very beginning of PS operation, and showed that the missing masses which are associated with the production of a baryon preferred some well-defined values, the first indication of what is known today as the 'peripheral' production of baryonic states.

The same principle, applied in 1964 to pion-proton collisions, where bosons plus one proton are produced, led to the discovery of several massive mesons. The search for meson resonances soon took advantage of a new technique: the wire spark chamber, which was invented at CERN by F. Krienen and which is now, connected on-line with a computer, of wide-spread use in high energy research.

An aim of the missing-mass experiments is to find how large is the population of excited baryons and mesons. So far, more and more excited states have been discovered as higher and higher mass regions have been investigated. We do not know how far the complexity of hadronic matter, this matter that can be created by pumping energy into a few particles, can go. Is there a 'uranium' for these particles? It is to pursue this kind of research into the region where still heavier bosons could be produced, that a CERN-Swiss group is preparing to work with the more energetic

particles available at the 76 GeV Serpukhov accelerator.

Another avenue of research that has a strong CERN imprint is the study of proton-proton scattering. This started in the very first years of PS operation, when the proton beam was that scattered out of an internal target. Later (1965) the study benefited greatly from the existence of an ejected proton beam. (The slow ejection was by itself a remarkable feat of the CERN accelerator experts.) Precise measurements of the proton-proton differential cross-section at small, as well as at large, scattering angles, revealed that the proton is not a point-like 'elementary' particle but has a complex structure, of about 1 fermi (1×10^{-13} cm) radius, whose boundaries become sharper as the collision energy increases. The experiment is still going on as one feels that better precision and higher energies can give a clue to the nature of the complexities hiding inside the nucleons.

The study of neutrino interactions is an interesting story. It started unsuccessfully when in 1961 a still inhomogeneous and inexperienced group tried to observe interactions of neutrinos produced by the secondary beams created in the PS, and made some mistakes in evaluating the fluxes of particles available. In the meantime, physicists from Columbia working at Brookhaven, discovered that the neutrinos produced by muons behave differently from those produced in nuclear beta-decay; an unexpected result of deep significance for the understanding of the weak interactions.

Further experiments at CERN, both with spark chambers and with a heavy liquid bubble chamber, coupled with original improvements in the handling of the secondary beams (the famous neutrino horn of S. Van der Meer), brought to Europe other important results in this field. For instance, it was found that the proton behaves also for neutrinos as a complex body of about 1 fermi radius, and not as a point, as many theoreticians expected. Furthermore, the neutrino-nucleon cross-section was observed to increase as the energy of the neutrino increases. This suggested that the neutrino, which at the energies explored

Wide gap spark chambers detecting charged particles in a 'missing mass' type of experiment recently completed at the proton synchrotron. This particular experiment extended the search, which had previously revealed seven new mesons, into a range where still heavier mesons could be detected. The search is to be extended still further in 1970 by a CERN/Serpukhov team at the 76 GeV proton synchrotron in the Soviet Union.

thus far interacts with matter only very weakly, could perhaps become as strongly interacting as the hadrons, at cosmic energies. The clarification of this point must wait for accelerators providing beams of energy substantially higher than those available at present.

The search into the unknown is pursued with a high energy machine like the PS, not only by attempting experiments that can bring to light new unexpected phenomena, but also by testing the limitations of theories whose validity is well confirmed by the existing experimental evidence. In CERN the best example of research of this kind is the test of electrodynamics performed by measuring the magnetic moment, μ , of the muon. Quantum electrodynamics predicts, with an uncertainty of some units in the last figure, that the gyromagnetic ratio of the muon has the

$$\text{value } g = \frac{4 \mu}{eh/mc} = 2.00233174.$$

Measuring the precession of mono-energetic muons in a magnetic field it is possible to check this prediction with a precision that depends on the energy of the muons. The first attempt was started at CERN in 1959 by a team of European and American

physicists, using 200 MeV/c muons produced by the synchro-cyclotron. The result (1961) was $g = 2.002324 \pm 0.000010$. This confirmed the theory within about 1 part in 10^5 . In 1964, a new apparatus was built that permitted the use of 2 GeV/c muons from the PS, and the work of five years has now produced the figure $2.00233232 \pm 0.00000062$. This checks the theoretical expectation within some parts in 10^7 . We are now starting to assemble an apparatus which, using 3.2 GeV/c muons, will permit a gain of another factor of at least ten in precision.

Obviously, the possibility of pushing the test of a theory to these limits has an esthetic beauty in itself, but it also gives us more confidence in our understanding of the vast class of phenomena governed by electrodynamics. On the other hand, as the precision of these measurements progresses even further, we will be brought inescapably into contact with the limitations of the theory, and will have to face the reasons why the theory is no longer valid beyond a certain level.

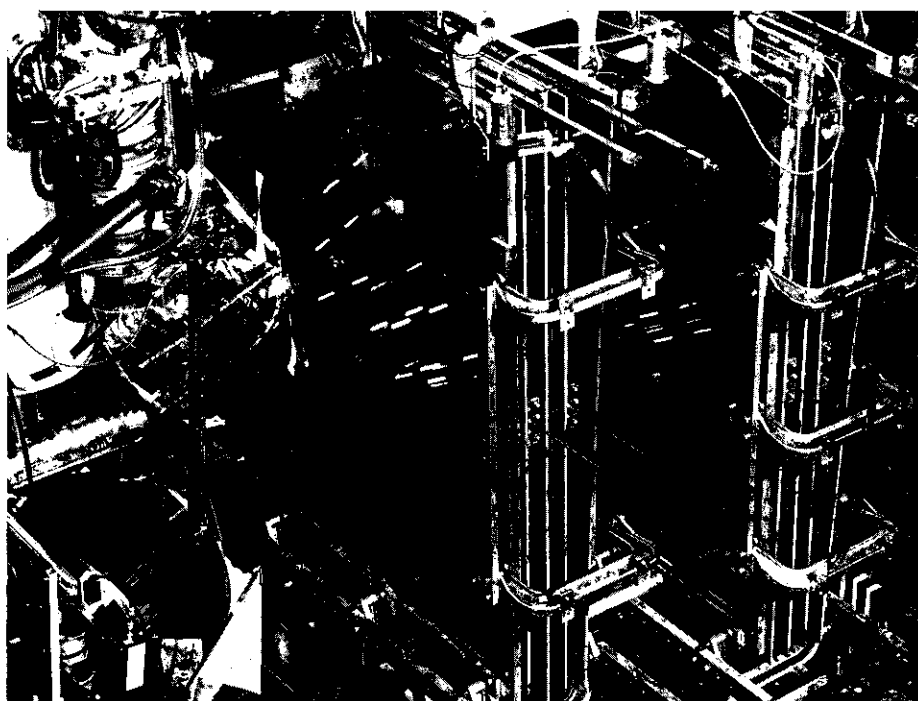
I will end this selective description of the PS research programme with two examples of more recent trends. One project started in 1964, after the discovery by Fitch and Cronin at Brookhaven in 1963 of the anomalous decay of the long-lived (5×10^{-8} s) neutral kaon into two pions — anomalous because the decay into two pions is permitted for the short-lived (8×10^{-10} s) kaon but should not occur, according to the known rules of quantum mechanics, for the long-lived. What produces this anomaly? The problem is still open, notwithstanding the concentrated effort of many teams of physicists on both sides of the Atlantic. What is involved here is the apparent violation of what was believed to be one of the fundamental tenets of quantum mechanics, the invariance of CP (charge and parity conjugation).

In CERN, no less than six teams have conducted some of the most elaborate and ingenious experiments, involving Cherenkov counters, optical spark chambers and wire spark chambers, in an attempt to resolve this anomaly. Next year three new experiments will continue the search.

The common aim of the second group of 'recent trend' experiments is the detailed study of the scattering of various particles by protons, so as to be able, for example, to establish the quantum numbers of the resonances produced, or the nature of the forces that give rise to the scattering.

Until a few years ago it was hoped that, at each energy, the precise measurement of the differential cross-section as a function of the polar angle of scattering, averaged over all azimuthal angles, could give sufficient information. It turned out that while this is perhaps true for the study of the states with the lowest quantum numbers, as soon as the complexity of the system increases it becomes imperative not to average over the azimuth. This means that we have to utilize not isotropic but polarized targets, where the protons have all their spins aligned in a fixed direction.

Scattering experiments with polarized targets have been vigorously pursued in CERN during the last few years, and the most advanced systems built thus far for high energy research have been realized



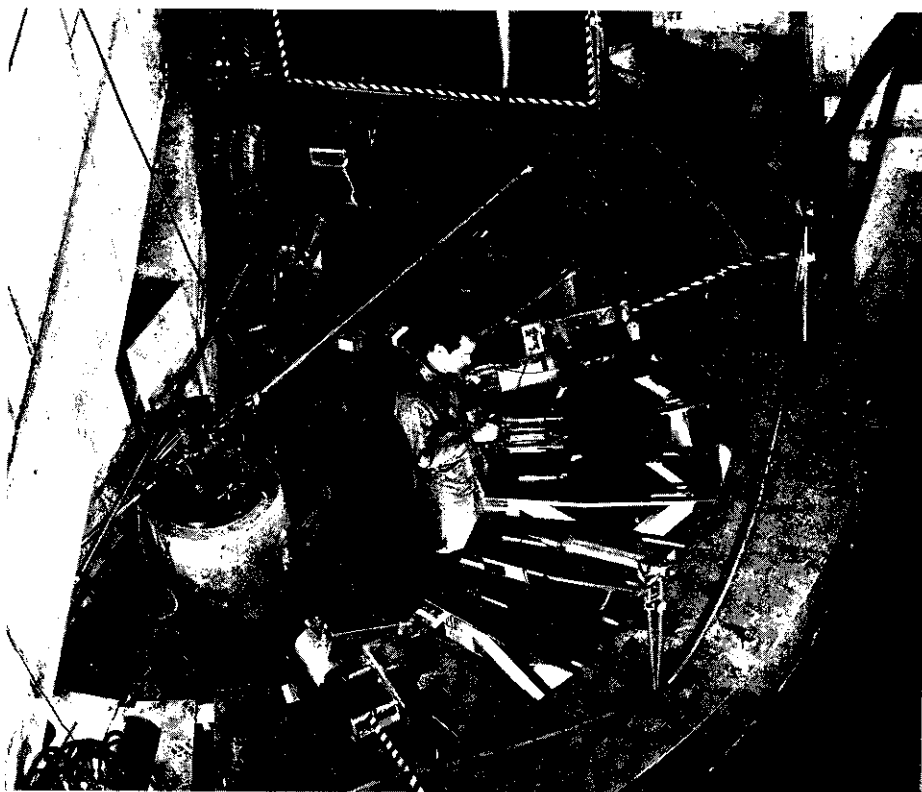
CERN/PI 211.1.69

The muon storage ring which was used in the measurement of the 'g-2' of the muon. This experiment was the most refined test to-date of the limits of the validity of quantum electrodynamics. A fan of counters to detect the electrons produced as the muons decayed, can be seen inside the ring.

here with the help of a team of physicists from the solid-state laboratory of A. Abraham in Paris. Three teams are at present carrying out experiments of this kind, with targets in which up to 50 % of the protons are polarized.

The fact that I have described only six lines of research that have developed with success around the PS during the last decade, should not give the impression that the many other experiments concluded or in progress are less interesting or less promising. And the fact that I reported the results in a rather simple way should not give the impression that the knowledge acquired is commonplace and somewhat anticipated.

It is the habit of people who try to interrogate Nature and, from the answers, to formulate new questions, to show a certain detachment and apparent coldness towards the finished experiments, even when the results are new and of great moment. This is because the scientist is trained to accept Nature as the norm of truth, and Nature's ever deeper and more astonishing variety is to him a continuous reminder of his ignorance. But there is no doubt that in the experiments I have described, as also in many of the others, the results were radically different from what experimentalists and theoreticians expected. Ten years ago we were convinced that the properties of strongly interacting elementary particles, in the GeV ranges and beyond, could in some circumstances be similar to those of a hard ball and in others to those of centres radiating a few kinds of mesons and baryons. The weak interactions were expected to be all of one type, obeying the rules learned from the behaviour of the decay of nuclei. In both cases we were grossly wrong, and if I am allowed to enclose within a unique frame the complex variety of phenomena that has manifested itself during the last ten years, I would say that as the energy per particle increases, all interactions — strong, electromagnetic and weak — are showing the common property of producing complex states, of ever increasing mass and rather constant lifetime: a mechanism that resembles the opening of a Pandora's box



CERN/PI 17.1.66

containing more and more winds as more energy is compressed into it.

The problem that we are now facing after ten years of research is, 'What kind of wind is contained in our Pandora's box?' That elusive stuff is called by the more determined physicists 'quarks', by others 'partons' (a synonym of dust). Whatever its name, the most astonishing property of this 'matter' is its ability, given enough energy, to build structures of greater and greater complexity, short-lived in our time-scale, but lasting long enough in the particle's time-scale, to possess well defined structure.

Faced with this new, complex world, we find ourselves (to finish with a timely comparison) like a man from the moon who from his experience was led to think that atoms could combine only in the simple molecules found in rocks and dust — the molecules that even the scorching solar wind is not able to destroy on the lunar surface. On landing on our planet, he discovers that the possibilities of the world of molecules are much more numerous and complex. That carbon, hydrogen, oxygen and a few other atoms, when put together in a 'gentle' way, can give rise to organic molecules that are rather unstable but are of almost infinite variety and millions of times heavier than those of the inorganic world.

How large can the big 'molecules' built with quarks or partons become; and how do they behave? These are the questions that our work has allowed us to formulate and that summarizes the direction of our future efforts.

It is for these reasons that I think that here in CERN we can feel confident of having fulfilled, during these ten years,

the augury made by Niels Bohr at the PS inauguration ceremony on 5 February 1960.

'The main human lesson drawn from investigations of phenomena ever more remote from ordinary experience is the recognition of the inseparability of objective knowledge from our ability to put questions to Nature by means of experiments suited to give unambiguous answers. It is therefore imperative that physicists taking part in such inquiry can have the opportunity of getting experience about all aspects of the situation. This would, however, be impossible for scientists from countries with more limited resources, if it were not by means of such co-operative efforts as those we are witnessing in CERN.'

And for the same reasons I feel that I can paraphrase the famous answer given by Faraday to the Minister who was asking whether his research on electromagnetic induction was leading to something useful. While Faraday said 'Sir, I do not know to what it will lead, but I am sure that eventually you will tax it', I think that to the same question, asked about high energy physics, we can reply, 'Sir, I do not know to what it will lead, but I am sure that eventually you will need it to understand what you are'.

2. Bubble chamber experiments

J. Meyer

Before the PS came into operation it was evident that a great deal of physics research could be undertaken with bubble chambers, the principle of which had just been discovered by Glaser and which were coming into use in great numbers in the United States. CERN plunged into the use of this technique constructing hydrogen and heavy liquid (to take propane or freon) chambers and supporting the operation for many years of chambers constructed in some Member States.

A whole series of complex technological problems had to be tackled with regard to the bubble chambers themselves, the particle beams to feed them and the techniques for their analysis. Successful and, in some cases, original solutions in the provision of pion, kaon, proton and anti-proton separated beams, and in the processing of events recorded on photographic film have enabled more than 20 million pictures to be taken and analysed by European physicists over the past ten years, producing important results.

The bubble chamber is, in a way, a complementary instrument to electronics equipment. It enables collisions to be detected and measured with uniform efficiency in all directions. On the other hand, only about ten incident particles may be analysed per PS cycle. Electronics equipment can accept over 100 000 particles, but their detection efficiency is generally strongly dependent on a complicated geometric arrangement of detectors. The heavy liquid chamber adds to detection possibilities since it may record and yield efficient measurements of electrons and gamma rays, which is more difficult with hydrogen chambers.

The physics results obtained from bubble chambers have been largely the result of collaborations between various European groups, some of which have included CERN scientists and some of which have been entirely external groups.

These large collaborations have been necessary to tackle the problem of obtaining significant statistics — hundreds of thousands, even millions, of pictures must be taken and the processing of this mass of information is long and complex. The collaborations have been set up between different groups in different Member States and to a lesser extent in other European countries or in the United States. In this way over a million events have been measured in the last twelve months.

In a short summary it is not possible to enumerate all the results obtained over the past ten years since the PS started operating, because they are so numerous and also because it is not always easy to judge their intrinsic value: what was important yesterday may not be so today and results which are considered of little account today may prove to be important tomorrow in the light of theoretical developments. Therefore, I shall limit myself to giving a sample of certain important studies and cases where the contribution made by European Laboratories was of a

A photograph taken during the latest series of neutrino experiments at CERN. The heavy liquid bubble chamber was filled with propane and the photograph shows the interaction of a neutrino with a 'free' proton, the first time such interactions had been observed. The neutrino enters from the bottom of the photograph and interacts with a proton to give a proton (short track to the right) a muon (long upward track) and a positive pion which decayed into a positron ('the tight spiral').

pioneering nature: when the discovery of phenomena was made in Europe or when it was made simultaneously with USA work, or when the results obtained from pictures taken at CERN made a decisive contribution towards a better understanding of important physical processes.

I shall list some major results obtained with hydrogen and heavy liquid chambers in three broad fields of elementary particle physics: weak interactions, the discovery and study of particles and resonances, and the study of the production mechanism in high energy collisions.

Weak interactions

- 1) Verification of the rule $\Delta S = \Delta Q$. This rule states that the distribution in time of neutral kaons decaying into a pion and a lepton pair follows a well defined law. A heavy liquid chamber experiment showed that within experimental errors, the law is valid.
- 2) The study of leptonic decays of charged sigma hyperons in a batch of more than a million sigmas has made it



possible to measure the ratio of the axial and vector coupling constants and to check the agreement with theory. On the other hand, a search of decays contrary to the rule $\Delta S = \Delta Q$ was undertaken and an upper limit to the rate of violation of this law was obtained. Lambda hyperon leptonic decays were also analysed in order to measure the ratio of the coupling constants.

- 3) Various experiments were made to verify the law $\Delta I = 1/2$ in strange particle decays.
- 4) Precise measurements were taken of the form factor of the positive kaon decaying into a pion, a muon and a neutrino.
- 5) Large heavy liquid bubble chambers provide an adequate target for the study of neutrino interactions. This is a most interesting field and the CERN chamber, exposed to neutrino beams has provided valuable information on the 'elastic' interaction of the neutrino with a neutron yielding a muon and a proton.

6) One of the great discoveries of recent years has been the decay of the long-lived neutral kaon into two pions. This phenomenon indicates a CP violating kaon decay and numerous experiments have been carried out in Europe and in the United States to measure the decay rate. The literature contains various contradictory results on the rate into two neutral pions. The measurement in a heavy liquid chamber experiment at CERN gave a value which was not in disagreement with the 'super-weak' theory.

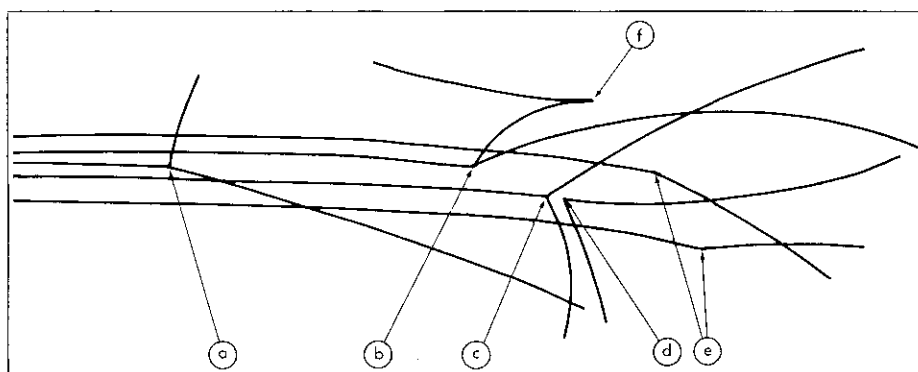
- 7) Precise measurements have been taken of the average life-times of the neutral xi and the positive and negative sigma hyperons.

Particles and resonances

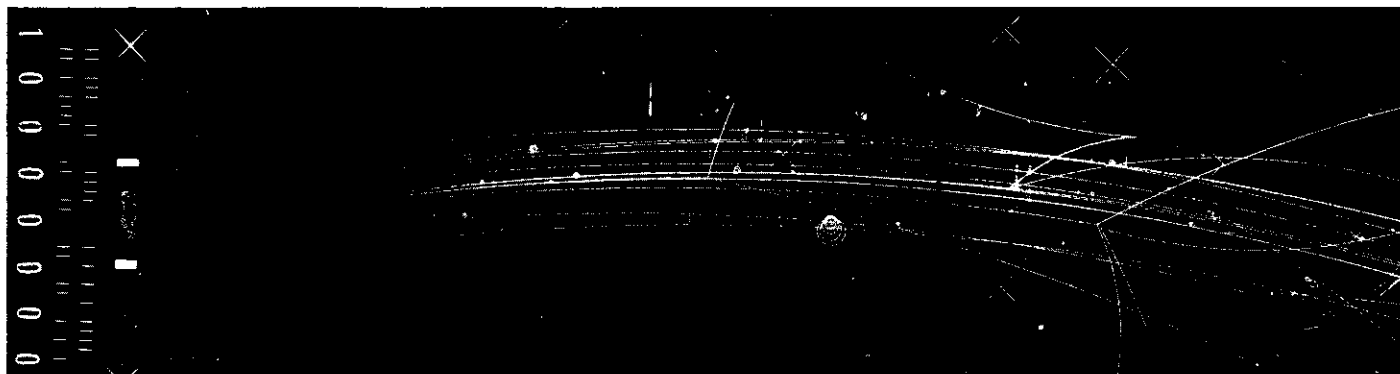
- 1) The anti-particle of the xi-hyperon, with strangeness -2, was discovered during the study of antiproton-proton collisions at 3 GeV/c.
- 2) The relative parity of the lambda and neutral sigma hyperons was found to

be positive from a study of the decay of the sigma into a lambda and an electron pair.

- 3) Different meson resonances have been discovered and in many cases their branching ratios and quantum numbers have been measured, in particular the following states: f^0 , A_1 , A_2 , C , D , E , the $K\bar{K}$ threshold effect, g , K^* (1400), L (1800). The importance of the contribution of physicists using pictures taken at CERN may be appreciated when one considers that at the present time only about thirty meson states have been conclusively identified.
- 4) The spin and the parity of K^* (890), whose existence was firmly established previously, have been measured by an original method using stopping antiprotons.
- 5) Baryon resonances of strangeness -1 in the mass region 1600 to 1900 MeV have been the object of an exhaustive study in a systematic 'formation' experiment. A new resonance Λ (1830) has been discovered and its spin and parity have been determined. Spin and



The ten millionth photograph taken in 1968 with the 81 cm hydrogen bubble chamber which came to CERN in 1961 initially on loan from Saclay. Positive kaons with a momentum of 0.98 GeV/c enter from the left. Two of them decay (e) while three others interact with protons in the chamber: at (a) an elastic scattering takes place, at (b) the interaction gives a pion, a positive kaon (which decays at (f)) and neutral particles, at (c) the interaction gives a positive pion, a proton and a neutral kaon which decays into two charged pions, at (d). The 2 m hydrogen bubble chamber also reached ten million pictures in September of this year.

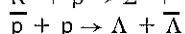
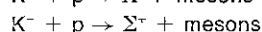
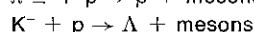
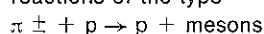


parity together with branching ratios have been successfully measured for Λ (1660), Λ (1670), Λ (1690), Σ (1760) and Λ (1815).

- 6) Three baryon resonances of strangeness -2 have been identified by means of European bubble chambers: $\Xi^*(1820)$, $\Xi^*(1930)$ and $\Xi^*(2530)$ — these constitute about 50% of the Ξ^* family currently known.

High Energy Production Mechanisms

- 1) Since the first experiments in 1960, it has become evident that a large number of high energy collisions are of a 'peripheral' nature. This means that in reactions of the type



baryons are produced preferentially with a low kinetic energy. The study of many reactions with a momentum exceeding 3 GeV/c has shown subsequently that 'peripheralism' is a dominant characteristic in high energy interactions.

- 2) The characteristics of bubble chambers which enable several reactions to be studied simultaneously have made possible the discovery of the importance of two-body and quasi two-body reactions. This affects reactions of the type $A + B \rightarrow C + D$ where C and D are either stable particles or resonances. At high energies these reactions are responsible for a sizable fraction of the total cross-section.
- 3) The differential cross-sections for thirteen quasi two-body channels have been analysed in detail and breaks have been shown to exist there. These results indicate that the structure observed in a channel may be correlated with the nature of the particles (or trajectories) exchanged. The measured cross-sections were compared with various theoretical models.
- 4) Information has been obtained on the nature of exchanged particles by measuring the density matrix elements of the resonances produced in quasi two-body reactions, for example — the

study of $K^*(890)$ produced in the reactions $K^- + p \rightarrow \bar{K}^*(890) + \text{nucleon}$ and $K^+ + p \rightarrow K^*(890) + p$ at high momenta.

- 5) Backward peaks have been discovered in the quasi two-body reactions for pion-proton and kaon-proton interactions. They are evidence for the baryon exchange mechanism and have been interpreted in terms of this mechanism.
- 6) A systematic study of the variation of two-body and quasi two-body cross-sections has been made in terms of the incident momentum. It was found that they varied as p^{-n} and all the reactions could be classified roughly in four groups, according to the value of n, each group corresponding to exchange processes of a well defined nature.

From this list it is evident that European physicists, using bubble chamber photographs taken at CERN, have made a very positive contribution to elementary particle physics. Although the bubble chamber is an instrument essentially adapted to the study of strong interactions, significant and sometimes very precise measurements have been taken in the field of weak interactions. In the domain of strong interactions, physicists have succeeded in discovering numerous resonant states and in determining their properties and the properties of others already discovered elsewhere. The results thus obtained have made a significant contribution to the main theoretical developments of the last few years, namely the classification of particles and resonances by unitary symmetry models and Regge trajectories.

Finally, several extremely important experimental laws governing the field, which was completely untouched ten years ago, of high energy collisions were discovered in bubble chamber experiments and their interpretation has stimulated theoreticians to a deeper insight into elementary particle interactions.

Suppose the PS is running non-stop all the year round, accelerating 10^{12} protons per pulse every two seconds... try to guess (or even calculate) how long you would need to run the machine —

- a) To accelerate the same number of protons as there are in a small drop of water (50 mm^3) ?
- b) To accelerate as much charge as passes through a 100 watt bulb (250 volt mains) in one second ?
- c) To accelerate as many protons as would fit onto a CERN COURIER page ($21 \times 30 \text{ cm}^2$) if they could be laid side by side ?

Answers at the bottom of the column.

Nature, it seems, is the popular name for milliards and milliards and milliards of particles playing their infinite game of billiards and billiards and billiards.

This is a grook (short aphoristic poem) called 'Atomyriades' from the book 'Grooks' by Piet Hein produced by MIT Press, Cambridge, Mass. (\$1.5 paperback).

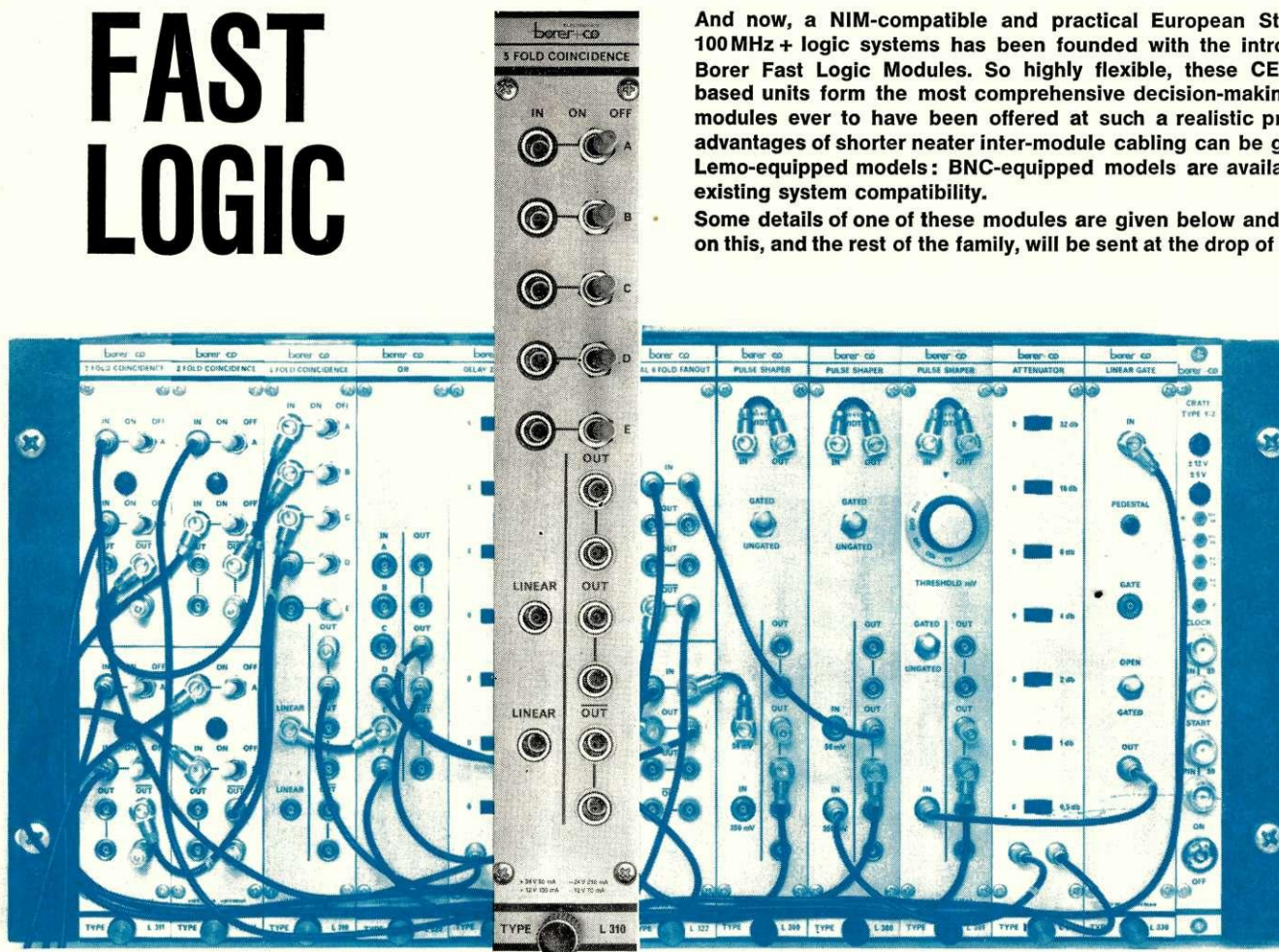
What does a European pay to have CERN in 1969 ? It depends a little where he comes from but, looked at in terms of Swiss francs per head, it is not too frightening :

Austria	0.63	Italy	0.485
Belgium	0.94	Netherlands	0.90
Denmark	1.12	Norway	0.85
Federal Republic			
of Germany	1.01	Sweden	1.37
France	0.99	Switzerland	1.38
Greece	0.17	U.K.	0.96

It averages out at 0.90 Swiss francs per man, woman and child in the twelve Member States. The price of a litre of beer. And some might say that it is not a bad idea to deprive at least the child of a litre of beer in this way.

Intelligence to build a proton synchrotron...
unfortunately did not display sufficient
age of the earth. The first forms of life
c) 4000 million years which is about the
About 2 months
a) About 1000 years

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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.

Inputs

Impedance	50 ohms $\pm 2\%$
Reflections 'ON'	20% max (capacitive)
Reflections 'OFF'	15% max (inductive)
Voltage	— 700 mV typ. — 600 mV min. } for coincidence
	— 100 mV max. for anti-coincidence
Overlap	LIN 2 ns min. for singles 2 ns min. for 5-fold
	OUT, $\overline{\text{OUT}}$ 1.5 ns min. for singles 1.25 ns min. for 5-fold

Linear outputs

Impedance	High, 16 mA current sources. Unused outputs need not be terminated.
Rise Time	1.8 ns max.
Fall Time	2.0 ns max.
Width, equal to	(Overlap + 1.0) ns for singles (Overlap — 1.0) ns for 5-fold
Rate	200 MHz max.
Propagation delay	6 $\pm$ 0.75 ns for singles Decreases by 0.5 ns max for 5-fold
Feedthrough	± 15 mV max for n-1

Logic outputs

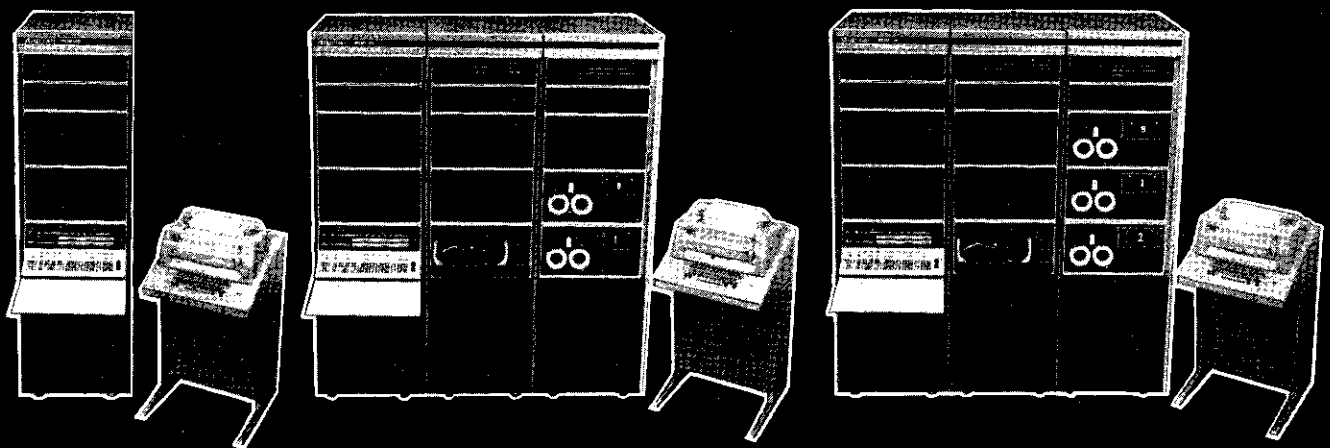
Impedance	High, 32 mA current sources, unused outputs must be terminated.
Width	OUT 8.5 $\pm$ 1 ns
Width	$\overline{\text{OUT}}$ 9.0 $\pm$ 1 ns
Rise time	OUT 1.5 ns max.
Fall time	OUT 2.2 ns max.
Rise time	$\overline{\text{OUT}}$ 2.0 ns max.
Fall time	$\overline{\text{OUT}}$ 2.2 ns max.
Rate	Greater than 50 MHz
Propagation delay	10.5 $\pm$ 0.75 ns for singles Decreases by 0.5 ns max for 5-fold

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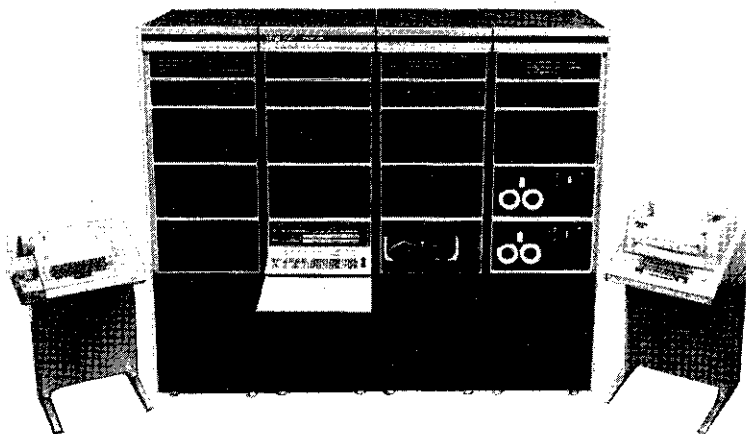
meetings of DECUS, the Digital Equipment Computer Users Society.

Now that you've discovered a medium-sized computer that's anything but a pain in the neck, undoubtedly you'll want to find out all about it.

PDP-15/10 4,096 18-bit words of 800-nanosecond core memory. Teletype Model ASR-33 console teleprinter. COMPACT Software System including assembler, editor, debugging aids, and mathematical and utility routines.

PDP-15/20 Advanced Monitor System: 8,192 words of core memory, KSR-35 Teletype for extra reliability, two DECtape transports and control units, high-speed paper tape reader/punch, Extended Arithmetic Element for high-speed arithmetic operations and register manipulation. Advanced Monitor System with FORTRAN IV, FOCAL-15, MACRO-15 macro assembler, linking loader, batch processor, system generator, scientific library, and comprehensive debugging and utility routines.

PDP-15/30 Background/Foreground System: 16,384 words of core memory, KSR-35 Teletype, Extended Arithmetic Element, Automatic Priority Interrupt System, Memory Protect System, high-speed paper tape reader/punch, three DECtape transports and control unit, real-time clock, and a second on-line Teletype for background use. Background/Foreground Monitor System combining all Advanced Monitor functions with concurrent execution of real-time foreground



technology. Expanded instruction set. Improved expandability. Not new because PDP-15 users can draw on the software and applications expertise that stand behind several generations of Digital computers. Some 900 of our machines are in use in Physics applications throughout the world.

Major areas include Nuclear data acquisition and analysis, reactor and instrumentation control and film scanning. Not to mention hundreds of other applications in various sciences.

In addition to all the standard PDP-15 software, new users can share in the Program Library and exchange of information at regularly scheduled

tasks and program development or other lower-priority background computation.

PDP-15/40 Disk-Oriented Background/Foreground System: 24,576 words of core memory, KSR-35 Teletype, Automatic Priority Interrupt System, Memory Protect System, high-speed paper tape reader/punch, two DECtape transports and control unit, RF15 DEC-disk control and two RS09 random-access disk files, real-time clock, and a second on-line Teletype for background use. Disk-oriented version of the Background/Foreground Monitor System, allowing concurrent execution of real-time tasks and background computation, in addition to all standard Advanced Monitor functions.

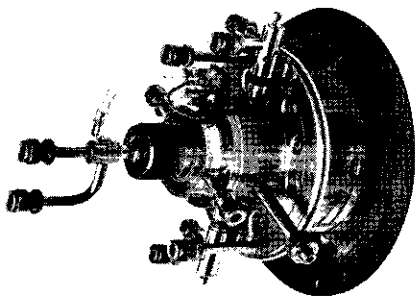
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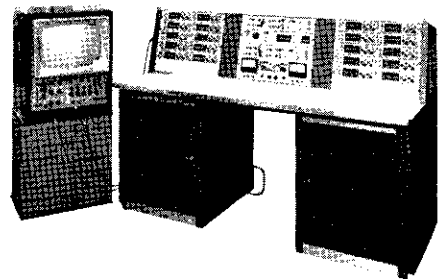
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Co-ordinate and Digital Products

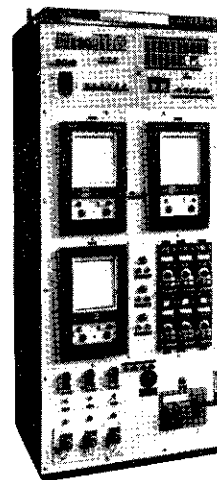
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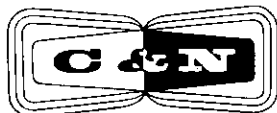
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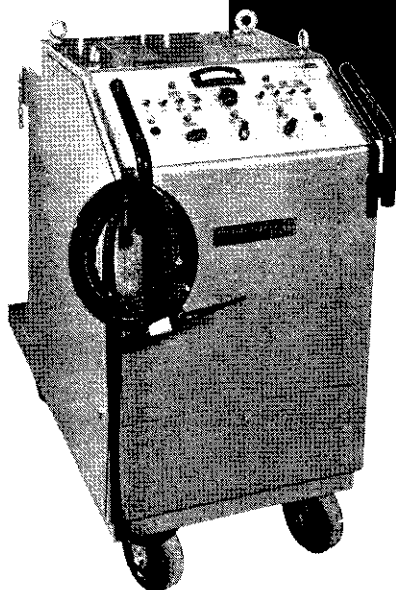
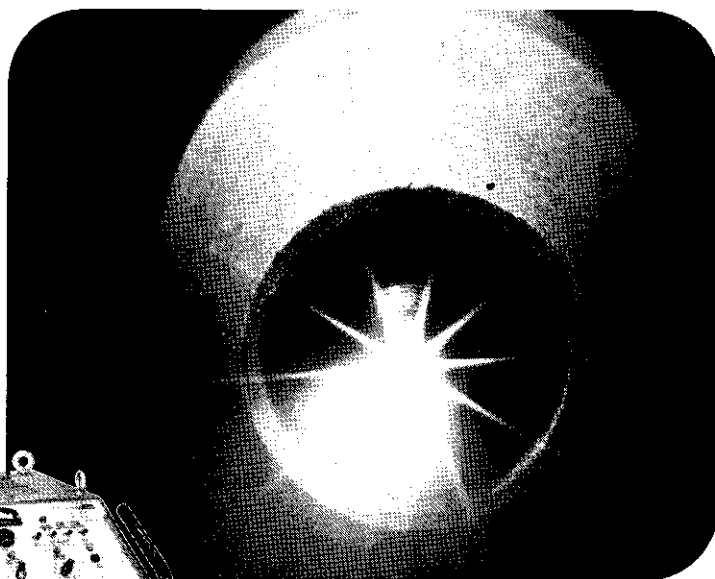
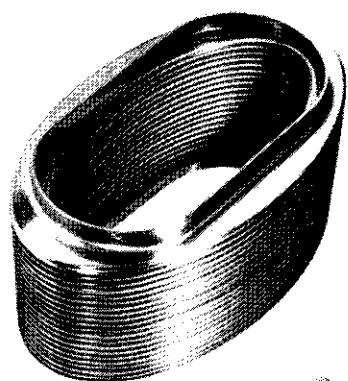
Soufflet elliptique en acier AISI 304 destiné à l'accélérateur Proton-Synchroton.

Diamètre extérieur 180 x 104 mm
Soudé avec l'appareil PLASMA-FIX 40

Intensité du courant de soudage 2,8 A.

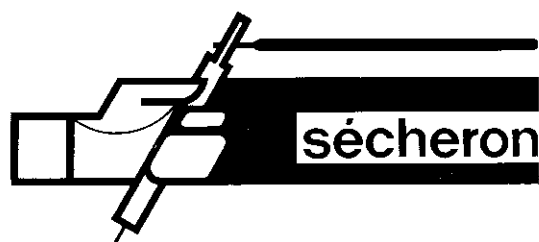
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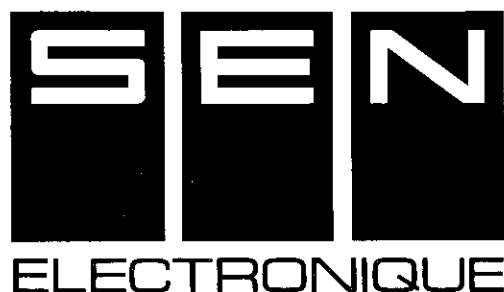
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Type 2004 FOUR-FOLD CAMAC SCALER

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



DESCRIPTION AND SPECIFICATIONS.

1. Input

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

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

2. Overflow outputs

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

3. CAMAC Functions Used in the Module

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

Clear and initialize: Reset all scalers, Clear all overflow flags and set the L-mask at 0000.

Inhibit: Close the input gate of all 4 scalers.

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

4. Physical

Single unit CAMAC module, fully shielded construction.

Representatives throughout Europe and The United States

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les chambres à fils en régime proportionnel ouvrent des horizons nouveaux

CARACTÉRISTIQUES

Temps mort inférieur
à 10^{-6} seconde par fil.
Résolution meilleure
que 100 nanosecondes.
Auto-déclenchement.
Sorties logiques fil par fil.
Possibilité de coïncidences
avec une autre chambre
ou un détecteur.

APPLICATIONS

Détection sélective des particules
en fonction de leur pouvoir d'ionisation.

Basses énergies :
Plan focal de spectromètre.
Localisation spatiale
de rayons X et de neutrons.
Chromatographie β .

Hautes énergies :
Localisation de traces.
Hodoscope à faible pouvoir d'absorption.

Electronique :

Enregistrement des événements :
résolution ≥ 100 ns
Temps de lecture : environ 20 μ s

new possibilities with multiwire proportionnal chamber

CHARACTERISTICS

Dead time below 10^{-6} second per wire.
Time resolution better
than 100 nanoseconds.
No triggering DC high voltage.
Logical output for each wire.
Possibility of use in coincidence
with other chamber or detector.

APPLICATIONS

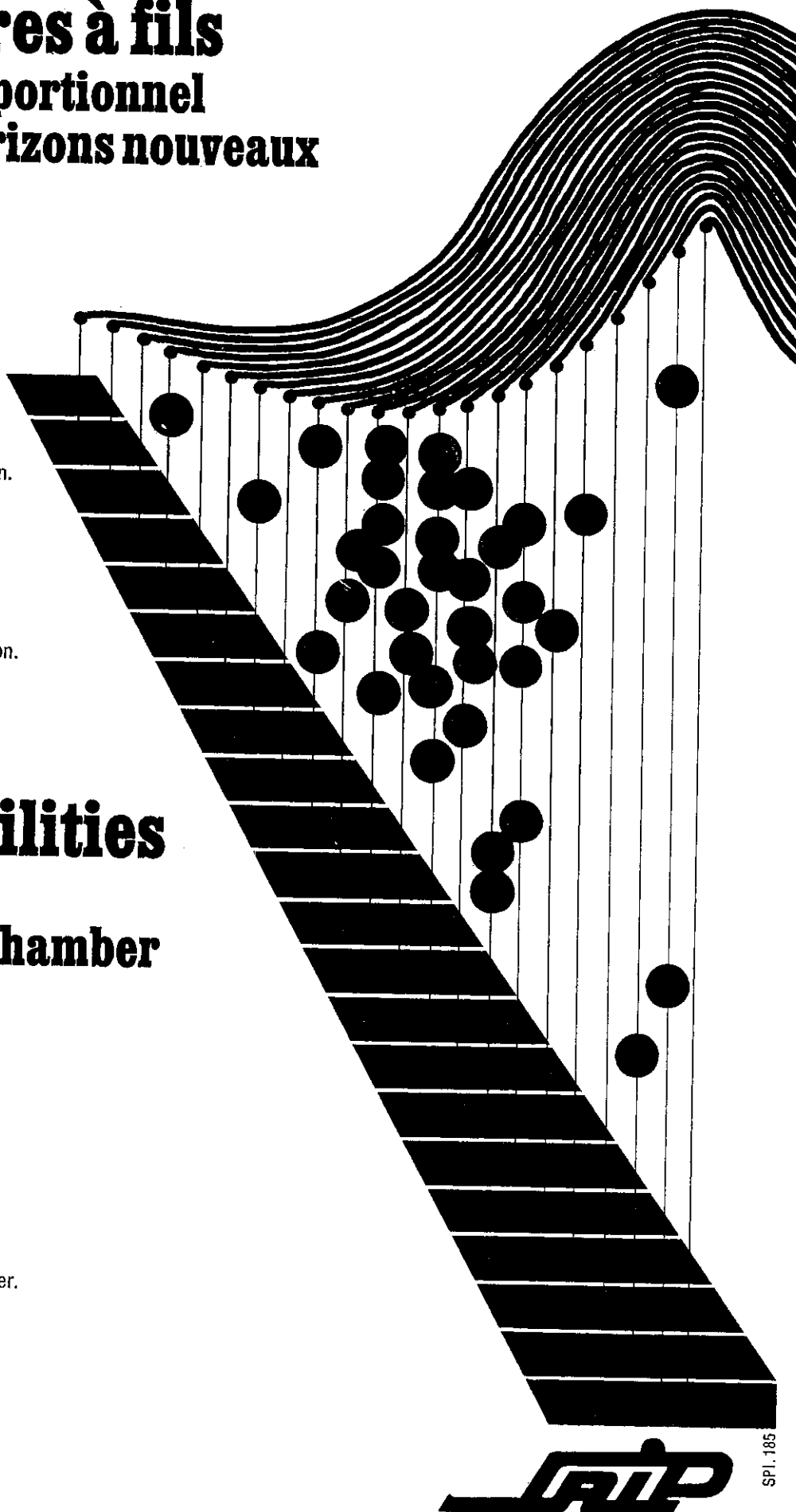
Detection selectivity for particles
of different ionizing power.

Low energy physics :
Localisation in focal plan of spectrometer.
Mapping in spatial distribution
of X-rays and neutrons.
 β chromatography.

High energy physics :
Localisation of particle trajectories.
Hodoscope with low superficial weight.

Electronics:

Event recording: resolution ≥ 100 ns
Read-out time: about 20 μ s



SPI. 185

SOCIETE D'APPLICATIONS INDUSTRIELLES DE LA PHYSIQUE
38, rue Gabriel Crie, 92, Malakoff, France, téléphone 253 87 20 +, adresse télégraphique : Saiphy Malakoff

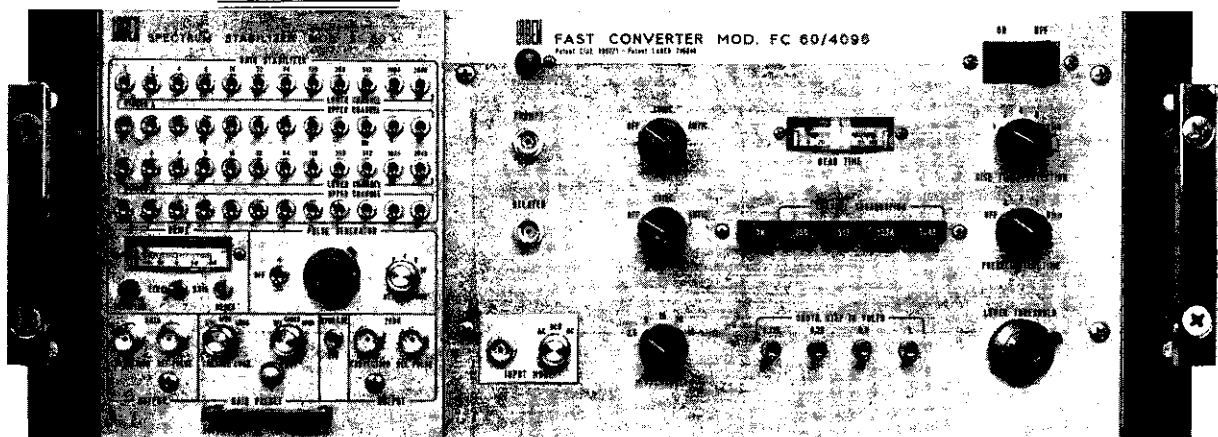
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EFFICIENCY AVAILABLE FROM MASS PRODUCTION

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equivalent clock rate

LABEN

- differential linearity : 0,1 %
- integral linearity : 0,04 %
- input mode : AC or DC coupled
: DC restorer
- number of channels : 4096



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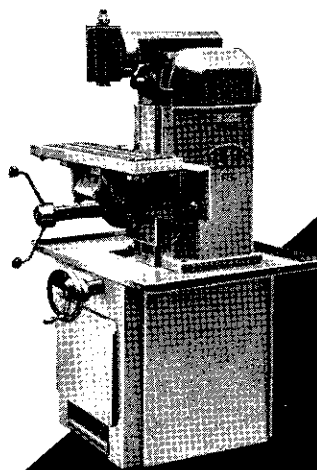
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Milano - Via E. Bassini, 15 - Telefono, 2365551 - Telex, 33451

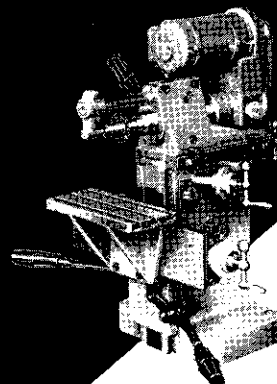
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GREAT BRITAIN AND IRELAND: Nuclear Enterprises Limited, Sighthill, Edinburgh 11 (Scotland) - ISRAEL: Palec Ltd., 7, Rishonim St. P.O.B. 1039 Ramat-Gan - NETHERLANDS: Intechmij N.V., Hoogkarspelstraat 68, Postbus 8068, Den Haag - NEW ZEALAND: A.A. Guthrie Ltd., 4 Adelaide Road, C.P.O. Box 1944, Wellington - NORWAY: H. Meltzer and Co., Bygdo Allé 23, P.O. Box 3038 Elisenberg, Oslo 2 - SWEDEN: Polyamp AB, FACK 17500, Jakobsberg
SWITZERLAND: High Energy & Nuclear Equipment S.A., 2 Chemin de Tavernay, Grand-Saconnex, 1218 Geneva (Enquiries handled also for Spain and Portugal)

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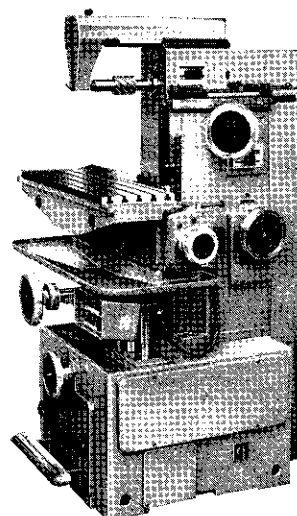
ACIERA



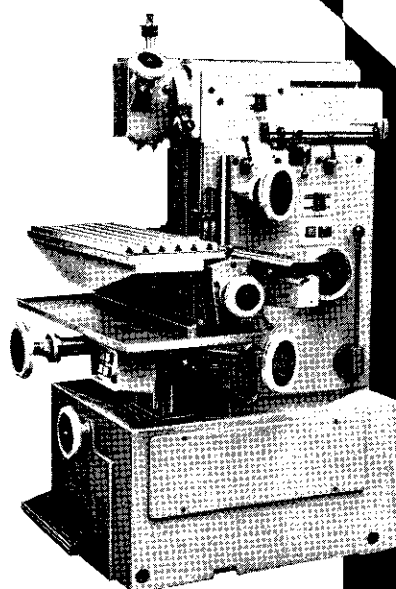
F3
200×600 mm



F1
100×220 mm



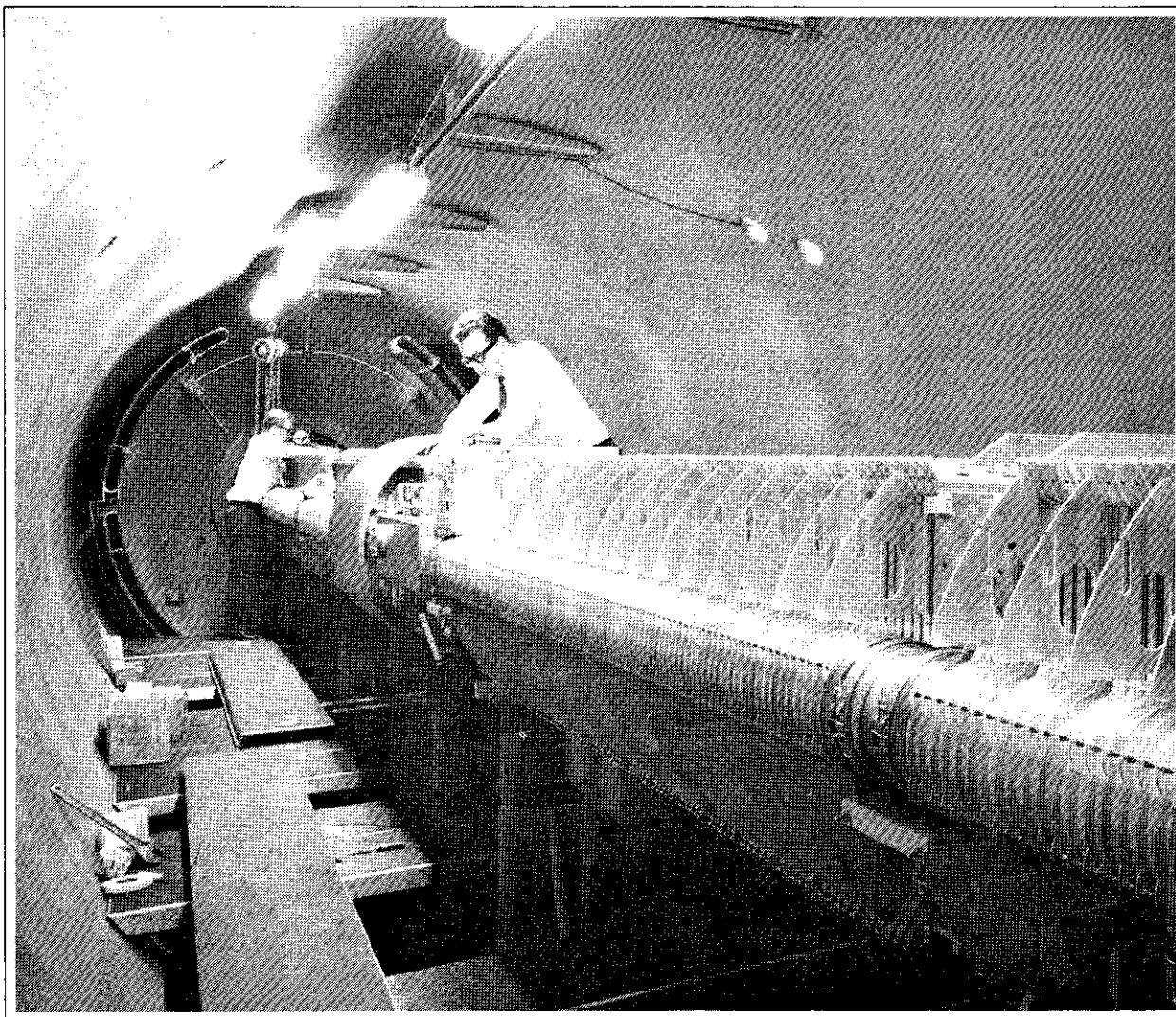
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F5
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You will admit, this is an achievement.

But it is only a fraction of our total capabilities. The range of scientific equipment which we manufacture is ever increasing and with that our skills

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Since late 1968,
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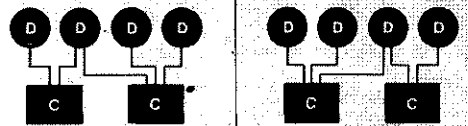
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(Multiple-Counter Experiment Logic)

a family of IC logic cards and bins
for versatile counter/computer interfacing.

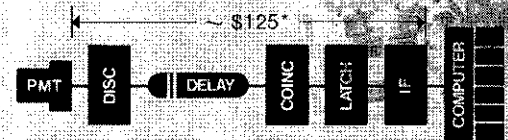
Innovated at UCRL and developed
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most economical logic system
available today for use with large
arrays of counters.



Coupled with high-performance low-cost
photomultiplier tubes, MCEL enables
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providing an average of more than
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All fast inputs and outputs are NIM-compatible
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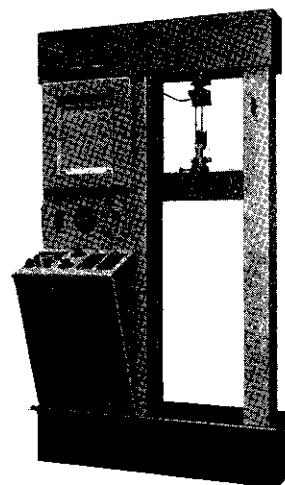
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first residual gas analyzer with
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Introducing non-stop RGA.



TM Electronic
Associates, Inc.



*my dear Watson—
two other great
detectors!*

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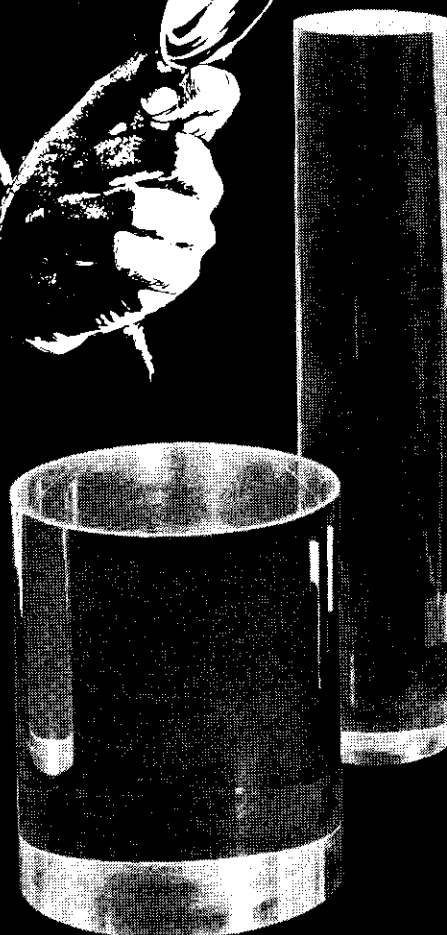
	NE 102A	NE 110
Light output, % anthracene	65	60
Decay time, ns	2.4	3.3
Light attenuation length, cm	170	250
Maximum emission, Å	4250	4300



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ZERO CROSSING

1 IN OUT

WIDTH

GATE UNGATE

2 IN OUT

WIDTH

3 IN OUT

WIDTH

4 IN OUT

WIDTH

EG&G
SER. 7042

MODEL T101/N
DISCRIMINATOR

INPUT THRESHOLD

IN OUT

WIDTH

OUT

SCALER

A OUT

B OUT

C OUT

D OUT

EG&G
SER. 6030

MODEL T1100A/N
DISCRIMINATOR

THRESH

50 100 200 300 400 500

INPUT ONE SHOT

VAR. WIDEL

INPUT ZERO

EXT. GATE

LOCKOUT

LAMP TEST

TRIGGER CONFIRM

OUTPUTS

HIGH LEVEL

LOW LEVEL

EG&G
SER. 6246

MODEL T120/N
QUAD DISCRIMINATOR

IN 1

WIDTH

OUT A

OUT B

IN 2

WIDTH

OUT A

OUT B

IN 3

WIDTH

OUT A

OUT B

IN 4

WIDTH

OUT A

OUT B

EG&G
SER. 8554

MODEL T105/N
DUAL DISCRIMINATOR

IN

THRESH

WIDTH

OUT A

OUT B

IN

THRESH

WIDTH

OUT A

OUT B

EG&G
SER. 8334

MODEL C142/N
QUAD DCB

DISC. COUNT BUFFER

1 IN THRESH

CLIP

2 IN THRESH

CLIP

3 IN THRESH

CLIP

4 IN THRESH

CLIP

STROBE

EG&G
SER. 8105

MODEL TD101/N
DIFFERENTIAL DISC.

INPUT

DELAY

SCALER

IN

OUT

A

B

C

D

EG&G
SER. 7505

MODEL TR204A/N
DUAL UPDATING DISCRIMINATOR

IN

INHIBIT

INPUT DC

CLIPPED

OUT A

OUT B

OUT C

OUT D

EG&G
SER. 6018

MODEL T101/N
DISCRIMINATOR

IN

THRESH

WIDTH

INHIBIT

GATE

OUT A

OUT B

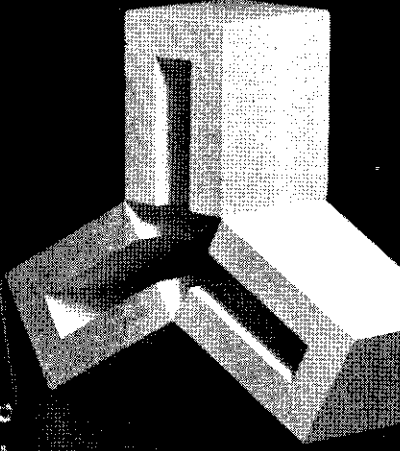
OUT C

OUT D

EG&G
SER. 6175

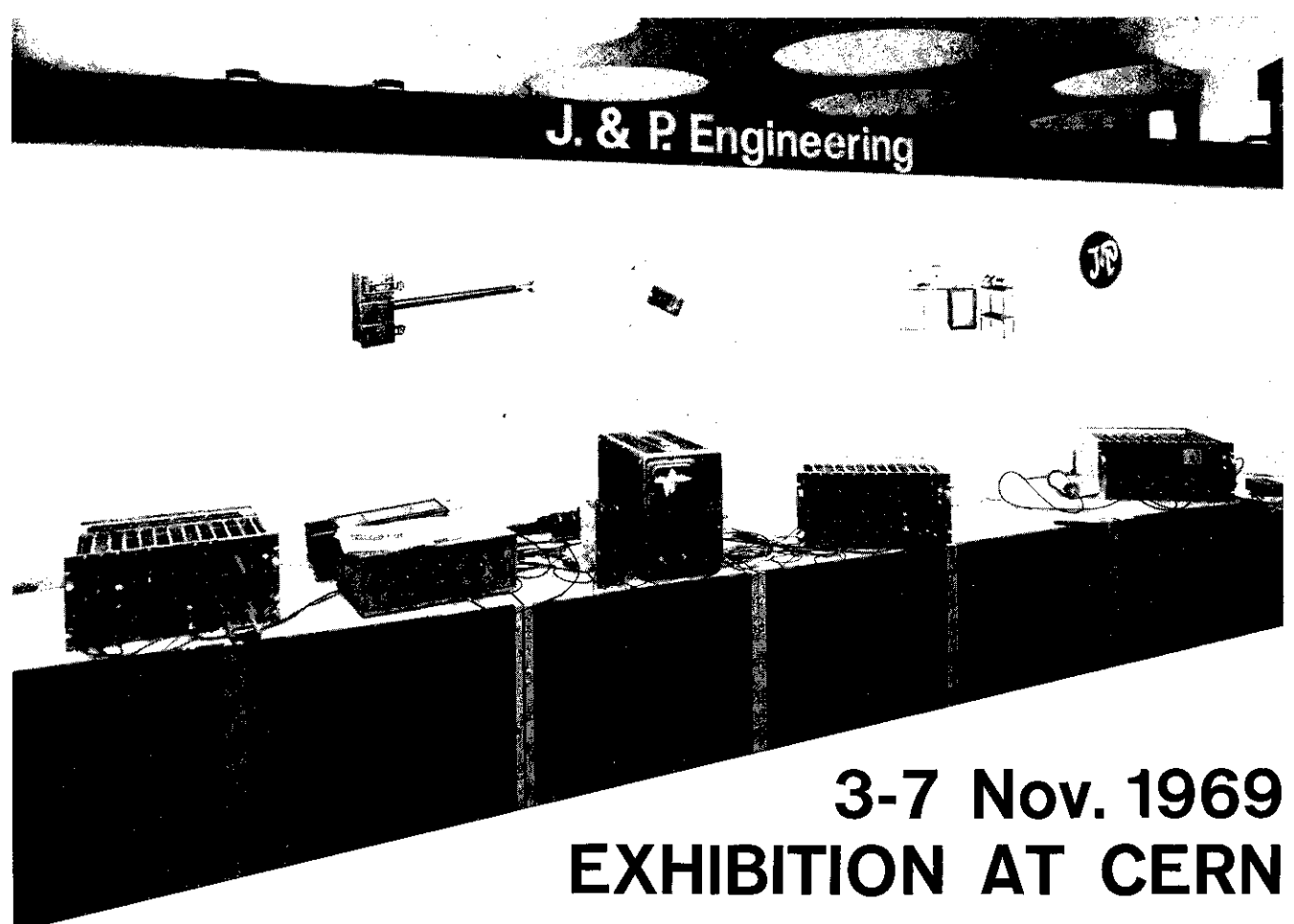
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J. & P. Engineering

3-7 Nov. 1969 EXHIBITION AT CERN

J & P as European Designers of NANOSECOND LOGIC

Zero crossing discriminator — Time jitter less than 250 pico seconds measured by our visitors.
Remote controlled delays — Our visitors couldn't find any reflections (nor. could we $\pm 2\%$).
Push button delays, attenuators, coincidences, OR gates leading edge discriminators and scalars were also shown.

J & P as MECHANICAL ENGINEERS

High vacuum systems, cryogenics, large magnetic field coils were too big to bring.
Epoxy resin mouldings, spark gap electrodes and examples of precision machining unusual materials aroused interest.

J & P as Producers of GENERAL NUCLEONICS

A Sodium iodide Spectrometer was on display.
How do we describe briefly the many new requirements we discussed?

DID WE MISS YOU ?

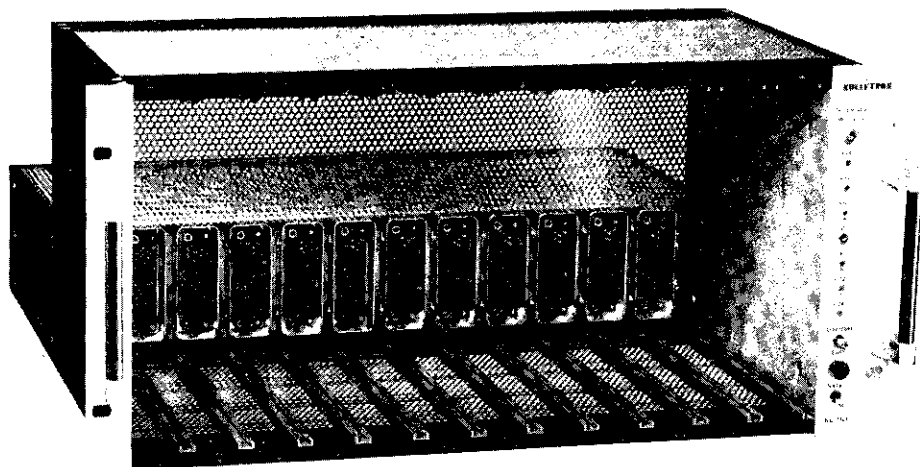
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J & P Engineering (Reading) Limited



AEC/NIM

19"-ÜBERRAHMEN MIT NETZTEIL



- $\pm 24 \text{ V}; 1,5 \text{ A}$
 $\pm 12 \text{ V}; 2 \text{ A}$
 $\pm 6 \text{ V}; 5 \text{ A}$
- NETZABSCHALTUNG
 BEI ÜBERLAST
- KURZSCHLUSSFEST
- THERMISCH GESCHÜTZT
- STABILER
 ALU-RAHMENBAU

ANWENDUNG: In allen Labors der Kernphysik, Hochenergiephysik und überall, wo vielseitige Impulsverarbeitung erforderlich ist, findet dieses Netzgerät mit Überrahmen Anwendung. Es entspricht der von der AEC (Atomic Energy Commission) herausgegebenen Norm bezüglich der Abmessungen und Versorgungsspannungen (TID-20893). **Alle auf dem Markt erhältlichen Einschubmodelle, die nach der AEC/NIM-Norm gefertigt sind, können in diesem Rahmen betrieben werden.**

AUFBAU: Die Spannungsversorgung (24 V, 12 V, 6 V) ist als Kompaktnetzteil ausgeführt und an der Rückseite des Überrahmens montiert. Als Steckverbindung zwischen Netzteil und Kassette dient der Stecker AMP N. 202516-3 mit den zugehörigen Kontaktverbindungen.

THERMISCHER SCHUTZ: Optische Anzeige der Innen-

temperatur bei 50° C und Netzabschaltung bei einer Kühlkörpertemperatur von 90° C .

KURZSCHLUSS-SICHERHEIT: Jede Spannung ist durch eine eigene Strombegrenzung gesichert, die auf 1,1 des Nennstroms eingestellt ist. Bei Kurzschlüssen, die zwischen zwei Spannungen auftreten, ist das Gerät durch Dioden bzw. Zenerdioden am Ausgang geschützt.

ÜBERLASTABSCHALTUNG: Die Überlastkarte trennt das Netzteil bei Kurzschluss gegen Null, Kurzschluss zweier Spannungen, Ausfall einer Spannung, Über- bzw. Unterspannung vom Netz. Die Überlastkarte ist in der Standardausführung des AEC-Rahmens nicht eingebaut.

Auf Wunsch kann statt 6 V auch 5 V Ausgangsspannung geliefert werden.

TECHNISCHE DATEN

NU 312 C

AUSGANGSSPANNUNG:

$\pm 24 \text{ V}, 1,5 \text{ A} / \pm 12 \text{ V}, 2 \text{ A} / \pm 6 \text{ V}, 5 \text{ A}$

GESAMTAUSGANGSLEISTUNG: 128 W

NETZKONSTANZ:

bei Netzspannungsschwankung $\pm 10 \%$

$\pm 6 \text{ V}: \leq 3 \times 10^{-5}$

$\pm 12 \text{ V}: \leq 1 \times 10^{-6}$

$\pm 24 \text{ V}: \leq 1 \times 10^{-6}$

TEMPERATURKOEFFIZIENT: $5 \times 10^{-5}/^\circ \text{ C}$

INNENWIDERSTAND: mit Steckverbindung 0,015 Ohm (alle Spannungen)

LASTKONSTANZ: $< 500 \mu\text{V}$ für Laständerung von 0 auf 100 % (ohne Steckerübergangswiderstände)

BRUMM:

$\leq 200 \mu\text{Vss}$ bei Leerlauf (für alle Spannungen)

$< 1 \text{ mVss}$ bei Vollast (für alle Spannungen)

WECHSELSPANNUNGS-AUSGANG: 115 ~, 0,5 A

NU 311 C

Wie NU 312 C jedoch

AUSGANGSSPANNUNG:

$\pm 24 \text{ V}, 1,5 \text{ A} / \pm 12 \text{ V}, 2 \text{ A} / \pm 6 \text{ V}, 2 \text{ A}$

GESAMTAUSGANGSLEISTUNG: 96 W

NU 310 C

Wie NU 312 C jedoch

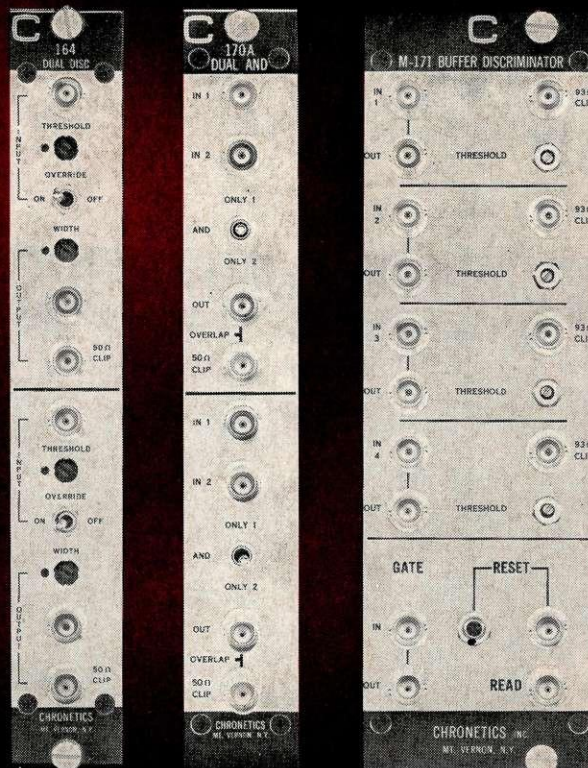
AUSGANGSSPANNUNG: $\pm 24 \text{ V}, 1,5 \text{ A} / \pm 12 \text{ V}, 2 \text{ A}$

GESAMTAUSGANGSLEISTUNG: 72 W



GESELLSCHAFT FÜR NUCLEONIC UND ELECTRONIC MBH

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Model 170A is a dual AND capable of resolving time of better than 1.5 ns at 200 MHz. Output is fast (1 ns rise and fall times) standard logic with output width precisely equal to input coincidence overlap timing. Mode selection for Only A, A and B coincidence, Only B. DC-coupled.

In Model 171 you can have four channels of Discriminator-Coincidence-Buffer operation with 5 ns pulse pair resolution at 200 MHz. A strobed coincidence preceded by discriminators. Variable input threshold. Coincidence resolution better than 1.5 ns. Front panel Gate, Read, Reset. All of the logic for fast hodoscopes without the usual expense.

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For more information on fitting lower cost Nanologic to your counting/logic needs, please write or 'phone.

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