M. A. GUNTHER

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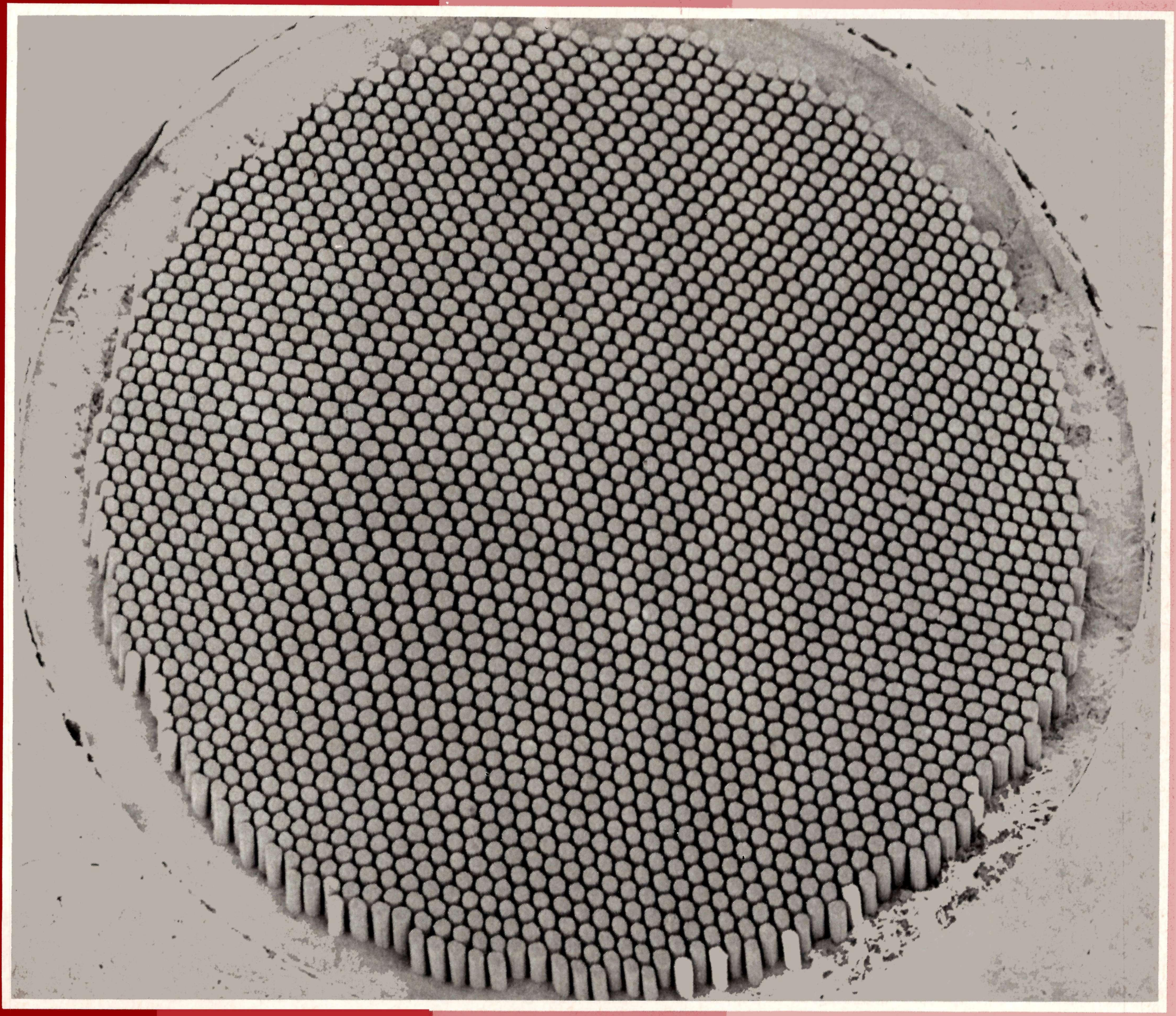

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Contents

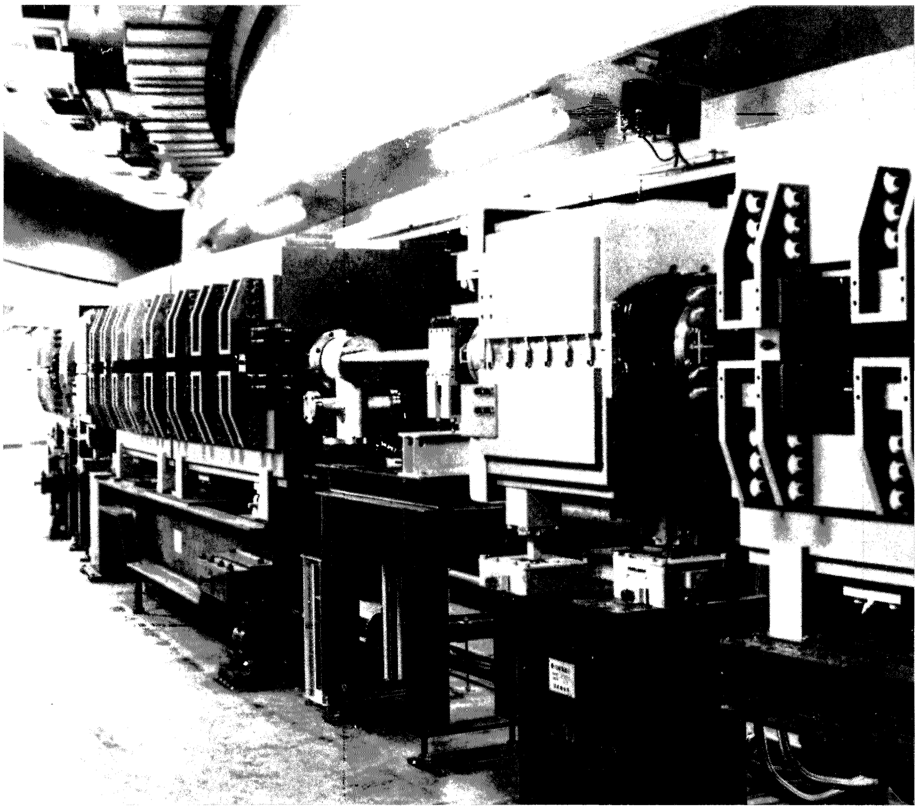
Around the Laboratories

Cover photograph: Etched cross-section of a niobium-titanium superconducting wire, 0.68 mm in diameter, such as is used in constructing the magnets for the Energy Doubler project at the Fermilab. The first magnet has rolled off the new production line and has achieved the desired field level (see page 143). The wire has 2300 superconducting filaments twisted and embedded in high purity copper. It can carry a current of over 240 A in a field of 5 T and at a temperature of 4.2 K. Twenty-three of them are formed into a flat cable in constructing the magnets. (Photo Airco)

Protons accelerated in KEK synchrotron

The main ring of the proton synchrotron at the Japanese National Laboratory for High Energy Physics, KEK. The synchrotron accelerated protons to 8 GeV in March. On the right can be seen several of the ring bending and focusing magnets.

(Photo KEK)



As we reported briefly in our March issue, protons were accelerated to 8 GeV in the synchrotron at the Japanese National Laboratory for High Energy Physics, KEK, on 4 March. This is the story of the last few months of the machine commissioning.

On 21 November, the first attempt was made to inject protons into the main ring from the 500 MeV booster. After an afternoon spent tuning the beam transport line between the two rings, injection into a d.c. field to hold 500 MeV protons was tried in the early evening. About three hours were needed to adjust the injection septums and the kicker and at 23.00 h the first full turn around the ring was observed. Working through the night achieved a fairly stable beam which lived for 10 ms. The booster was feeding in 2×10^{11} protons per pulse and about 10^{11} were circulating after injection.

At the beginning of December, attention concentrated on refined tuning of the synchrotron by moving around the tune diagram (adjusting focusing magnet settings) while the bending magnet fields were held constant. Eventually a beam lifetime of 250 ms was achieved (with ν_x = 7.18 — the design value is 7.25). Beam behaviour under the influence of various resonances was carefully investigated.

The next commissioning run began on 12 December when two of the three r.f. cavities in the main ring were in action and it was possible to attempt acceleration for the first time. There was no joy, possibly due to a mismatch between the magnetic field and the r.f. frequency or to a tracking error between the bending and quadrupole magnets.

A week later another attempt at acceleration was made and, after clearing some booster troubles, a small fraction of the injected beam was manoeuvred to an energy of almost 2 GeV. About midnight on 19 December, the beam was accelerated to 4 GeV but it was not stable and the peak energy that could be achieved varied from pulse to pulse.

A frustrating couple of months followed during which there were three machine runs without significant improvement in performance. There was also a three week shutdown to sort out some magnet problems in the low energy beam transport system between the preinjector and the linac.

Mid-February the machine was in operation again and it became clear that beam control via the r.f. acceleration system was the crucial problem. The beam monitor, position feedback and phase lock systems were improved and at the end of February, the beam could be accelerated up to transition energy at 5.27 GeV.

Success came a few days later. A machine run began on 3 March when, up to midnight most of the time was absorbed by tuning the r.f. system. The magnet power supplies were set to take the field up beyond the level corresponding to transition energy to a peak corresponding to 8 GeV. The first attempt at acceleration was at 0.30 h and at 3.00 h protons went all the way to 8 GeV for pulse after pulse in a pretty stable beam. The accelerated beam intensity was estimated at 2×10^{10} protons per pulse. (ν_x was set at 7.14 and ν_z at 7.19; sextupole correction magnets were not switched on.) On 19 March the magnet fields were run higher and a 10 GeV beam was obtained.

The KEK machine is the first attempt at proton synchrotron construction in Japan. We congratulate the Director of the Accelerator Department, T. Nishikawa, and his team on their impressive achievement. We welcome them to the high energy fold and wish our Japanese colleagues many years of good physics.

ECFA Meeting in March

The European Committee for Future Accelerators met at CERN on 29 March. ECFA is the forum for all components of the European high energy physics community — the Universities, the National Laboratories and CERN. There was a crowded agenda and we will briefly cover most of the topics which were discussed.

The Chairman, Guy von Dardel, reported on recent ECFA activities. The main ones were — ECFA sponsorship of the meeting at Frascati at the beginning of March (reported in the March issue) where the experimental programme at the PETRA electron-positron storage ring was discussed; further action on the Report of Working Group 3 which made recommendations on the relationships between the different parts of the high energy physics community; strong ECFA support of budget figures which would not damage the physics programme during the CERN budget discussions in December 1975, and ECFA's presence at the Serpukhov meeting in May (of which more news in our next issue) when von Dardel will lead the delegation of the CERN Member States. Von Dardel concluded by comparing the work of ECFA to the process of seeding clouds. If the work bears fruit one never knows whether the rain would have fallen in any case but the task of seeding the clouds certainly tries to ensure the rain.

Marcel Vivargent from Annecy presented preliminary information from another Working Group which has been assembling information on the support given to scientists from the Member States when they are working on experiments at CERN. There are big discrepancies between the allowances etc. which are allocated by the different countries and, when the survey is complete, action may be needed to attempt to even out the support for all the visiting scientists.

Herwig Schopper, Director of DESY, reported on the progress with PETRA. Construction is proceeding very quickly — a section of tunnel is already complete, orders are placed for many components and the first r.f. klystrons are scheduled to arrive mid-1977. First injection tests are scheduled for Spring of next year, the full ring will be assembled by the end of 1978 (though all the klystrons will not be in place by then) and experiments are scheduled to start mid-1979. Four interaction regions will be equipped initially and decisions on the first experiments will be taken in the Autumn of this year.

There was a long discussion on a paper entitled 'Guidelines for the work of ECFA' which attempted to summarize in a flexible way the aims and procedures which have been the basis of ECFA's work. Some people were worried about formalizing ECFA's operations too much in this way since they had proved adequate and adaptable in the past without such Guidelines. In particular, David Gray from Rutherford voiced what was subsequently referred to as the Gray criterion — 'If you doubt whether it is needed, leave it out'. The Guidelines were accepted for use within ECFA itself. Among the innovations that they establish is the possibility to have 'observers'. For example, given ECFA's interest in the PETRA experimental programme, the Director of DESY will be invited to ECFA meetings. Representatives from other non-CERN Member countries could also in principle attend. Another innovation is that Plenary meetings of ECFA will be open to the public.

John Mulvey from CERN, who will soon be returning to Oxford, made a spirited plea for ECFA to pick up again the responsibility which is indicated in its title — to think seriously about 'future accelerators'. He reviewed the plans in the USA and the USSR pointing out that both regions have projects at an advanced stage to meet physics needs which are now very obvious by providing the next generation of accelerators and storage rings.

In the USA, the Berkeley/Stanford PEP 15 GeV electron-positron storage ring has the go ahead, the Brookhaven ISABELLE 200 GeV proton-proton storage rings is a fully developed proposal which has more study money this year, and there are a range of higher energy accelerator and storage ring plans at Fermilab. In the Soviet Union there is a project for a 2-5 TeV accelerator which appears to be taken very seriously. For example, Soviet accelerator specialists are intending to visit CERN to learn from the experience in building the 400 GeV proton synchrotron, the SPS. Europe alone has nothing in view, beyond the completion of the SPS and PETRA.

Mulvey urged that ECFA should set up a Steering Group to examine the physics and technological prospects for future accelerators in Europe. ECFA took up this suggestion. Proposals for the members of the Group will be forwarded to von Dardel and the Group is expected to come into action quickly so as to make a first report at an ECFA Meeting in November.

Still on the topic of future accelerators, the ECFA policy to be followed at the Serpukhov meeting (concerning the building of 'a very big accelerator' as a world machine) was discussed. Von Dardel will lead the European delegation appointed by the CERN Scientific Policy Committee (the other five members being Ugo Amaldi, Kjell Johnsen, André Rousset, David Thomas and someone from the Federal Republic of Germany). The ECFA policy document finishes with words from the Helsinki Agreement on Security and Cooperation in Europe, which specifically mentions high energy physics as a field for cooperation — 'Scientific and technological cooperation constitutes an important contribution to the strengthening of security and cooperation... in that it assists the effective solution of problems of common interest and the improvements of the conditions of human life'. ECFA considers that also in this respect an international high energy physics project on a very large scale would be a particularly important step.

Leon Van Hove, Research Director General of CERN, reviewed the actions taken by CERN following the recommendations of ECFA Working Group 3 mentioned above. Some new principles have been established inside CERN to help smooth the working conditions of visiting teams. They concern particularly the degree of technical support supplied from within CERN and its balance with the technical support provided by home Laboratories. Contacts with Users are being expanded by improving the information flow and by transforming an ad hoc 'Commission of Associates' to be more representative of the User community. Finally the general question of communicating high energy physics is being tackled by more effort on the 'public information' front beginning with activities based on CERN itself.

John Mulvey reported the recent decisions on future computing facilities at CERN (covered in the March issue) and Mervyn Hine of CERN described plans in Europe for tests of high speed data links using both ground links and satellites. In his usual provocative way he described this as the solution to the present problem of trying to carry out a 21st Century Science using a 19th Century communications system. We will have an article on this topic in our next issue.

CESR – Cornell Electron Storage Ring

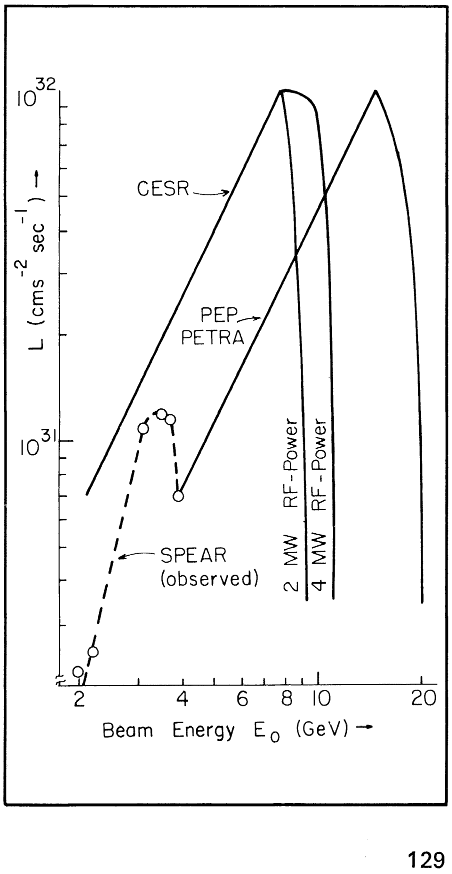
An electron-positron colliding beam facility is being planned at the Wilson Synchrotron Laboratory, Cornell University. The project calls for a ring to be built in the tunnel housing the 12 GeV electron synchrotron. The synchrotron will be used to inject both positrons and electrons into the storage ring, which is designed for a luminosity of 10^{32} per cm^2 per s at electron and positron beam energies of 8 GeV. Eventually, the energy range could be extended to 10 GeV by increasing the r.f. power.

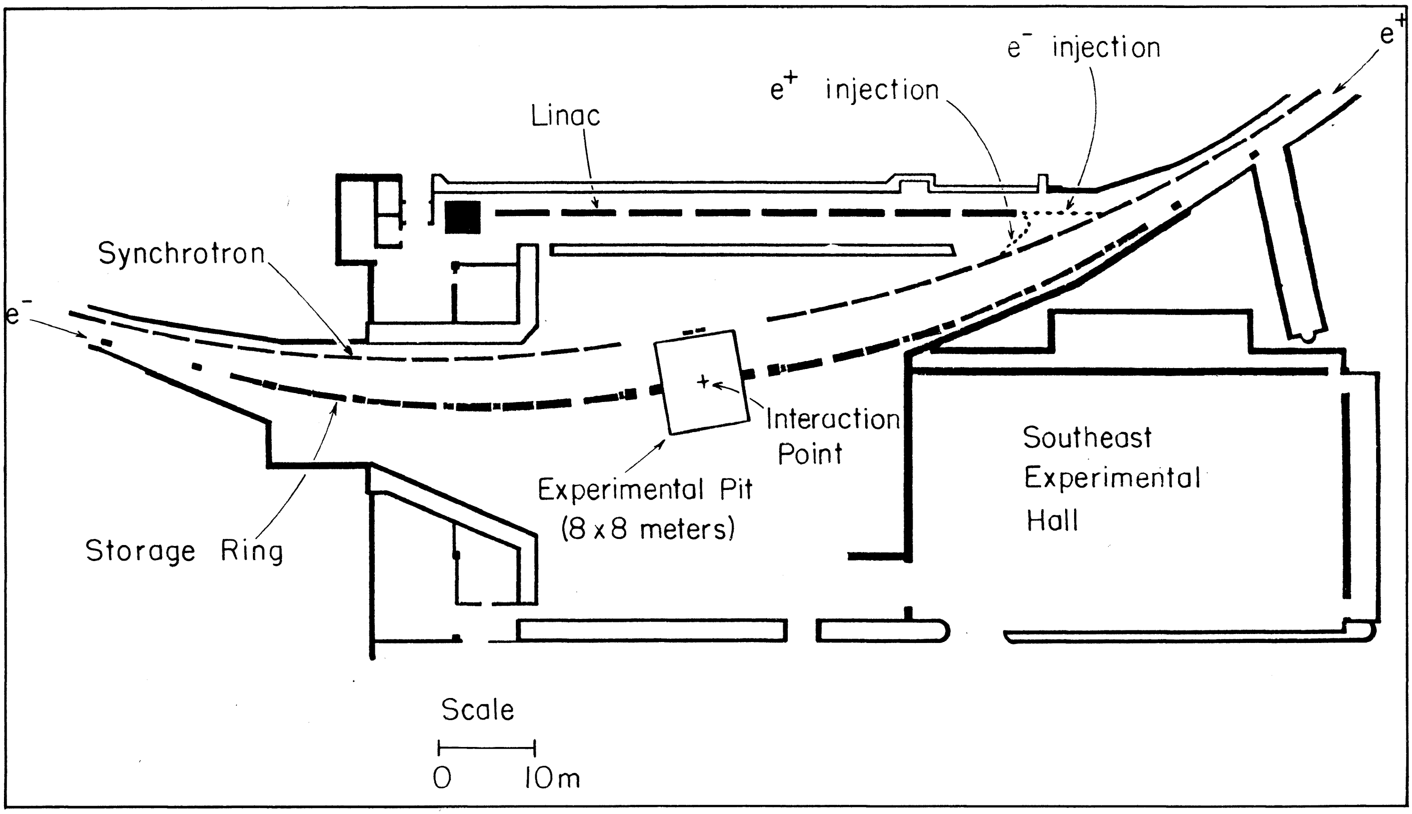
The Cornell facility is intended to complement the DESY (PETRA) and Berkeley/Stanford (PEP) storage rings which will operate at beam energies of 15 GeV and higher. These machines are designed for an optimum luminosity of 10^{32} at 15 GeV beam energy and in the lower energy range of 4 to 10 GeV their luminosity is appreciably less. CESR is optimized for just this energy region, intermediate between the presently operating SPEAR/DORIS rings and the future PETRA/PEP rings. For beam energies up to 10 GeV, CESR will have a luminosity several times greater than PEP and PETRA.

One of the drawbacks of storage ring operation is that all experimental areas must run at the same energy at any one time. Also major colliding beam experiments require many months to perform, even at high luminosity. Thus CESR, operating at high luminosity and low overhead cost in the lower energy ranges, can investigate phenomena from 4 GeV to 10 GeV efficiently, while PEP and PETRA press on with exploration of the higher energy regions using their maximum luminosity.

In May 1975, the Laboratory submitted a proposal to the US National Science Foundation (NSF) for construction of CESR beginning in 1976. Although this proposal was strongly supported by the NSF, it did not appear in the President's budget for Fiscal Year 1977. A new proposal of reduced scope was submitted to the NSF involving conversion to colliding beam operation using 'operating funds' augmented by less than two million dollars per year for three years. This proposal is currently being considered by the NSF. By directing nearly all the resources and efforts of the Laboratory towards this programme, beam could be injected into the storage ring during the summer of 1979. By that date, construction of a large magnetic detector for colliding beam experiments can also be completed and

Design luminosity as a function of beam energy for the electron-positron storage rings SPEAR, CESR and PEP/PETRA (PEP and PETRA being very similar). By increasing the r.f. power for CESR from 2 MW to 4 MW, operation can be extended to 10 GeV as shown. The high energy limit for PEP is shown for 9 MW of r.f. power with a total accelerating structure length of 76 m.





the experimental programme could get off to a flying start.

The NSF has recently approved the expenditure of $450 000 during 1976 for the development of final designs and prototype components. This work is proceeding at a fast pace with everyone pitching in while carrying on with synchrotron experiments. Animated discussions are held in all corners of the Laboratory on the design of the magnetic detector. Physicists from Harvard, Rochester, Syracuse and other research centres in the northeastern United States are enthusiastically taking part in the planning for this experimental facility. Prototype development of liquid argon shower detectors and large cylindrical drift chambers is already under way. Judging from the enthusiastic response from Cornell's 'neighbours' when the project was proposed, it is expected that more physicists will appear (with sleeves rolled up) to start working happily beside those already involved.

The electron linac from the Cambridge Electron Accelerator has been moved to Cornell and work is proceeding on the modulation of the linac beam and on the production of high intensities required for positron injection into the storage ring.

General description of the storage ring

The synchrotron and the 'separated function' storage ring will both run through the South Experimental Hall where, at the storage ring intersection point, the separation between the two will be increased to 5.3 m. The nominal separation between the orbits in the tunnel is about 1.6 m. The 'bulge' in the storage ring is achieved by introducing long drift spaces and a few magnets of higher than average field. The two long drift spaces will be occupied by r.f. accelerating cavities. For installing the detection systems, the interaction region has a free length of 7 m between quadrupoles and a pit depth of 3.8 m below the beam line with a pit area of 8 m × 8 m.

The North intersection region lies underground, at a depth of about 15 m under the surface of a sports field on the Cornell University campus. Due to anticipated budget limitations, the present proposal does not include a major experimental area at this interaction point. (Earlier plans called for excavation of a new experimental hall, including a three-story underground building for associated facilities.) However, specialized smaller experiments may be mounted in this area, where the total available space is 12 m long by 9 m wide, with an arched roof 4.5 m high (floor to ceiling). If necessary, a pit may be excavated, to allow a depth of 3 m below the beam line. The free length for installing detection systems in this interaction straight section is 5 m between quadrupoles.

The bending magnets and quadrupoles are designed for a peak operating energy of 10 GeV and the r.f. system is designed for initial operation at 8 GeV (2 MW). Additional power would give eventual operation at 10 GeV. The vacuum chamber is of extruded aluminium, similar to the SPEAR design, with a built-in water channel to absorb the heat deposited in the wall by the intense synchrotron radiation. Distributed sputter-ion pumps will be installed within the chamber in the bending magnets, to cope with the desorption of gas by synchrotron radiation. An average pressure of about 2×10^{-8} torr will be maintained with both beams circulating, giving a beam lifetime of about 12 hours.

A synchrotron radiation facility will be available to make use of the intense, collimated beam of X rays available from the storage ring.

Injection and stacking of beams

In order to achieve adequate average luminosity, it is crucial that injection of electrons and positrons be accomplished in a time which is short compared to the useful 'luminosity lifetime'. The storage ring is designed for single bunch operation. The relatively long damping times would require too long a wait between successive 'stacking' of single synchrotron beam bunches into a single bunch circulat-

Floor plan of the South intersection area of CESR, in the main experimental hall. The synchrotron and storage ring are 5.3 m apart at the interaction point while in the common underground tunnel the separation is about 1.6 m.

ing in the storage ring. An ingenious 'vernier phase-space compression' technique proposed by Maury Tigner will be used to overcome this difficulty. It uses multiple bunch acceleration in the synchrotron for filling a single r.f. bucket in the storage ring. At 8 GeV the positron filling time will then be 2.4 minutes while the higher electron output of the linac gives an electron filling time of one minute.

The injection for positrons proceeds as follows. Sixty evenly spaced bunches are injected from the linac into the synchrotron and accelerated to 8 GeV. These bunches are all extracted from the synchrotron in a single turn and injected into the storage ring, where the betatron oscillations are allowed to die down while the synchrotron receives and accelerates another burst of 60 bunches from the linac. These are then stacked on top of the bunches already circulating in the storage ring. The whole process is repeated at 60 Hz, until the total required charge has been accumulated in the 60 bunches in the storage ring.

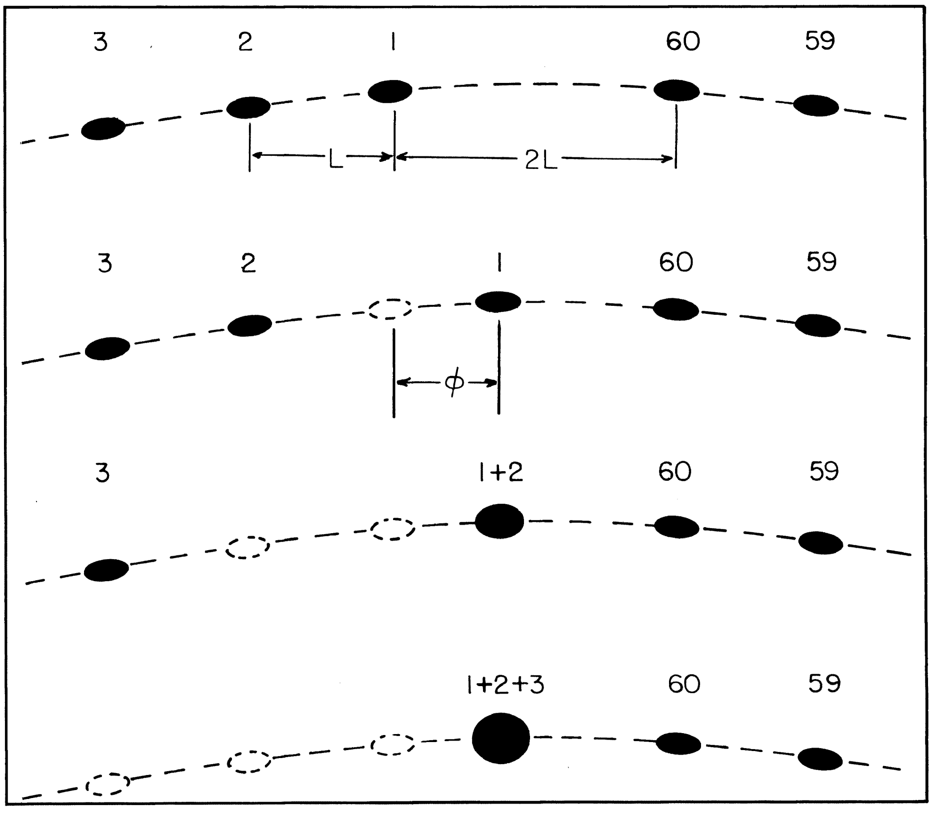
The vernier scheme is used to coalesce these bunches into one bunch. The circumference of the storage ring is larger than that of the synchrotron by one bunch spacing (L) and this provides the vernier phase difference between the synchrotron and the storage ring. There is thus an extra space, L, between the first and last bunches between the 'head' and the 'tail' of the 60 bunch train in the ring.

The first bunch at the head is extracted from the storage ring using a fast extraction scheme and reinjected onto the equilibrium orbit of the synchrotron at the peak of its cycle. The bunch travels around the synchrotron (advancing in phase with respect to its companions still in the storage ring) until it reaches the extraction kicker, where it is extracted and reinjected into the storage ring. This bunch has now advanced in phase as compared with its initial position. On the next synchrotron cycle, bunch number 2 is whisked from the storage ring and sent into the synchrotron for an extra turn past the extraction point to gain a full bunch-spacing L on bunch number 1, so that when reinjected into the storage ring it coincides in phase with bunch number 1. Then bunch number 3 gets the same treatment, except that three revolutions in the synchrotron are allowed before reinsertion into the storage ring, where it coincides in phase with bunches 1 and 2.

This routine is repeated 60 times in all, the last bunch making 60 circuits of the synchrotron to catch up with the first bunch. In order to allow thorough damping of the betatron oscillation between bunch manipulations, the cycle rate is kept at 30 Hz which gives a total time of 2 seconds for 'bunch compression'.

Magnetic detector

To examine as wide a range of phenomena as possible with limited resources, effort is concentrated on providing a single large, versatile detection system to be installed in the South interaction region. Various schemes are being considered for the ideal magnet — 'thin' superconducting solenoid, conventional solenoid, other more open geometries allowing access to the inner detectors, etc. No decision has yet been made, but partisans of each scheme are preparing their cases for the final selection. Prototype work on various particle detectors is proceeding and the detector is expected to be ready when the first stored beams are available in 1979. Further details of the chosen magnet, etc., will be presented as the design work progresses.



Various stages in the positron 'bunch compression' scheme for CESR. The top line shows part of the train of 60 bunches in the storage ring after repeated 'stacking' cycles. The second line shows the situation after bunch number 1 has been extracted from the storage ring, sent once around the synchrotron and reinjected into the storage ring. Bunch number 2 is then extracted, sent around for two revolutions and reinjected into the storage ring, coinciding in phase with bunch number 1, giving the situation in the third line. Bunch number 3 has three revolutions around the synchrotron to give the result shown in the forth line. The process continues until all bunches are compressed into one r.f. bucket.

Particle physics in education The Open University approach

Particle physics research has added a great deal of new information to our knowledge of Nature. This information is finding its way into human culture and one of the main channels is that of formal education. The new findings of particle physics are obviously projected in standard physics courses but the speed at which this comes about and the way in which it comes about varies from country to country and depends upon the level in the educational system at which it is introduced.

In the November issue of 1975, we described how proton-proton interactions recorded on bubble chamber film are being used at high school level in France to convey physics concepts such as the necessity and validity of quantum mechanics and the energy-matter relationship. This month we describe the way in which the Open University in the UK approaches particle physics at University level. The information comes from F.R. Stannard of the Faculty of Science at the Open University and some of it can be found in greater detail in the Proceedings of the 2nd Aix-en-Provence International Conference on Elementary Particles.

All science students at the Open University take a foundation course in science in their first year and the course is also open to non-science students. It has to be geared, therefore, to a broad audience and cannot presume previous science knowledge. Particle physics was brought into the foundation course with some trepidation, since 85 % of the students would not regard physics as their particular interest, but, so well did the Faculty of Science succeed in demystifying the subject, that a survey of 15 000 students who had taken the foundation course revealed that the 'Introduction to Elementary Particles' was considered the most interesting and stimulating feature of their entire first year studies.

The Open University is a magnificent new experiment in education where students study part time in their homes. Most of them are over 21 and in full time employment. The main channel for the teaching is by correspondence, particularly a series of special books written by the University staff. This is integrated with television and radio broadcasts put out by the BBC. Science students are provided with kits of equipment for performing experiments and there are intensive periods of Laboratory work at summer schools. They have some face-to-face tuition at local study centres. The student population is now 55 000 and 15 000 have already graduated. The intake for 1976 will be 17 000 students and there have been 53 000 applicants.

The 'Introduction to Elementary Particles' begins via written text explaining that in order to study particles they have first to be created. Through Einstein's equation, $E = mc^2$, it becomes clear that a source of high energy particles is needed. The simplest procedure for accelerating particles is to use a high voltage drop but this meets the problem of insulation breakdown. The use of cavities in a linear accelerator gets round that problem but comes up against a financial one — 'How many miles of accelerator can we buy?' This is countered in its turn by the synchrotron principle whereby the same cavities are used many times. But eventually the financial problem hits a second time in terms of the maximum diameter of the synchrotron ring that can be afforded. 'How much money is it reasonable to spend on an accelerator?' is not an academic question since the students are taxpayers and this question is brought up again later in the course. The newly created particles are separated by electric and magnetic fields and then comes the problem of detecting them which leads to a description of the bubble chamber.

The explanations of acceleration, beam design, and detection are kept as clear and simple as possible but students are not allowed to form the notion that the technology involved in high energy physics is trivial. The written text is complemented by a television programme in which M.J. Pentz and F.R. Stannard tour the PS accelerator and the 2 m bubble chamber at CERN. Starting from the proton source they trace the steps involved in the acceleration, production and separation of the particles. The design of the accelerator and bubble chamber are further explained by the use of models and, hopefully, the students gain a proper respect for the technology involved, without being overwhelmed by its complexity.

The course then turns to particle behaviour and properties in a rather novel way. Each student is supplied with a stereoviewer and a reel of three-dimensional bubble chamber photographs. A large part of the written text is then in the form of a commentary on what students see in the viewer as they work their way through the photographs.

The first picture is of a spiralling electron which serves to introduce the idea of magnetic curvature and ionization loss. Subsequent pictures are progressively more complicated and the series culminates with examples of associated production and interaction of strange particles. The idea of strangeness is introduced in order to explain the non-existence of certain reactions. The students are presented with lists of reactions, some involving particles new to them and, using what they have already learned from the photographs, they have to make baryon number and strangeness assignments for these new particles and make predictions concerning their interactions. Through these simple exercises, the students learn that strangeness is no more mysterious

The materials produced by the Open University are available for purchase as complete courses or as separate items. Free catalogues and brochures may be obtained from The Marketing Director, Open University, Walton Hall, Milton Keyes, Bucks., England.

than the more familiar electric charge — while it is true that in a sense we do not 'understand' either, both may be used as tools for ordering our observations.

The main experiment that is carried out in the student's home consists of a measurement of the mass of the muon. The students receive bubble chamber prints of pi-mu-electron decays at rest and a set of curvature templates. They measure the average projected momentum of the decay electron and, through a geometrical correction, the average momentum in space. It is a good enough approximation to assume that the electrons on average receive a third of the energy associated with the rest mass of the muon and the students can therefore arrive at a value for the muon mass. This straightforward experiment was remarkably popular — students liked the idea of actually measuring the mass of one of these tiny particles for themselves.

The work on elementary particles ends with a broad introduction to the idea of the SU3 classification scheme. Presented with the general layout of an SU3 decuplet, the students are given the properties of nine particles and are told to predict the properties of the tenth — the omega minus.

A radio programme is devoted to the discovery of this particle. M. Gell-Mann and Y. Ne'eman discuss how they came to propose the SU3 scheme, N. Samios describes the excitement he and his colleagues experienced when the first omega minus was discovered and, finally, R. Feynman is let loose on one of his inimitable inspirational pieces on how great it is to be a physicist at times such as these! A comparison is drawn between the SU3 classification scheme and Mendeleef's Periodic Table. The latter pointed the way to the quantum theory of atomic structure; will SU3 lead to quarks?

Having got the student under the skin of the high energy physicist and having got him interested in knowing what the structure of the proton might be, the problem of finance is brought back. What is it worth to know the answers to questions such as these? How can one possibly decide whether or not one should build a 400 GeV accelerator? In the week following their study of elementary particles, the students have to weigh up the pros and cons of a decision to build an accelerator. For this purpose they are supplied with a 'decision-making kit'. This consists of recommendations from scientific advisory committees, a minority dissentient report, conflicting letters to the journal 'Nature', extracts from governmental statements in Parliament, etc. The students are not asked to decide whether the government's decision to support the building of the CERN SPS was the right one but they are expected to appreciate the various factors that must be taken into account in making such a decision.

The Faculty of Science is now preparing another course called 'Understanding Space and Time'. The main theme will be the physicist's use of invariance principles — invariance under translations in time and space and under rotations in space leading to the conservation laws of energy, momentum and angular momentum. Invariance of physical laws from one inertial observer to another will lead to special relativity and between observers in gravitational fields and those undergoing acceleration will lead to general relativity.

Invariance under C, P and T will link again with particle physics. These will not be easy concepts to put across because a student cannot be expected to share a physicist's surprise at violations of parity or time reversal. 'Everybody' can tell left from right by checking where the heart is and cannot contemplate time reversal in the unscrambling of an egg. The course should be an exciting one, embracing particle physics at one end and cosmology at the other. It is hoped that it will be ready in 1978 or 1979.

Stannard maintains that those who attempt to popularize high energy physics could learn from the experience and the general philosophy adopted at the Open University. The philosophy is to take the 'mystique' out of the high energy physicist. Too often he is portrayed as some remote scientist thinking abstract thought, talking a language of his own, demanding vast sums of money for reasons that are too difficult to explain.

Helping the students to learn through their own experience, and through making their own deductions, goes some way towards breaking down the psychological barrier between them and the professional high energy physicist. Like the physicist, they too have been able to measure the mass of a particle, to make strangeness assignments, to make predictions. They too have come to realize that there is no easy formula for deciding at what level to support big science. This philosophy of getting the students to identify with the high energy physicist and his problems is one ingredient for success.

Another ingredient is the general attractive appearance of Open University teaching materials — the text printed in two colours and written in a friendly informal style, the beautiful three-dimensional bubble chamber photographs, the impressive views of CERN in the TV programme, and the sheer enthusiasm of the high energy physicist manifest in the radio programme. High energy physics can be a very visual and evocative subject. It can and should be made accessible to a wider public.

Around the Laboratories

CERN
Protons at the door of the SPS

On 5 April the beam transfer channel to convey protons from the proton synchrotron, PS, to the super proton synchrotron, SPS, was tested for the first time. Around 16.30 h the PS was ready to send protons at an energy of 10 GeV towards the SPS. They were spilled out over ten turns, using the continuous transfer technique, and pointed along transfer line TT2 towards the ISR. A switching magnet was then powered in TT2 to bend them underground along TT10 to the SPS.

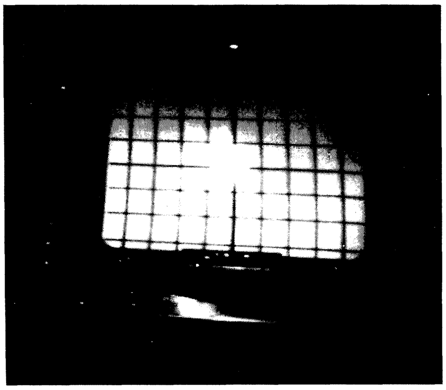
There were a few nail-biting minutes bringing this magnet on. At 16.35 h the very first pulse that the magnet operated, protons thumped into the beam stop temporarily positioned at the entrance to the SPS ring about 800 m down TT10. The protons were only 15 mm away their intended position horizontally and exactly at their intended position vertically.

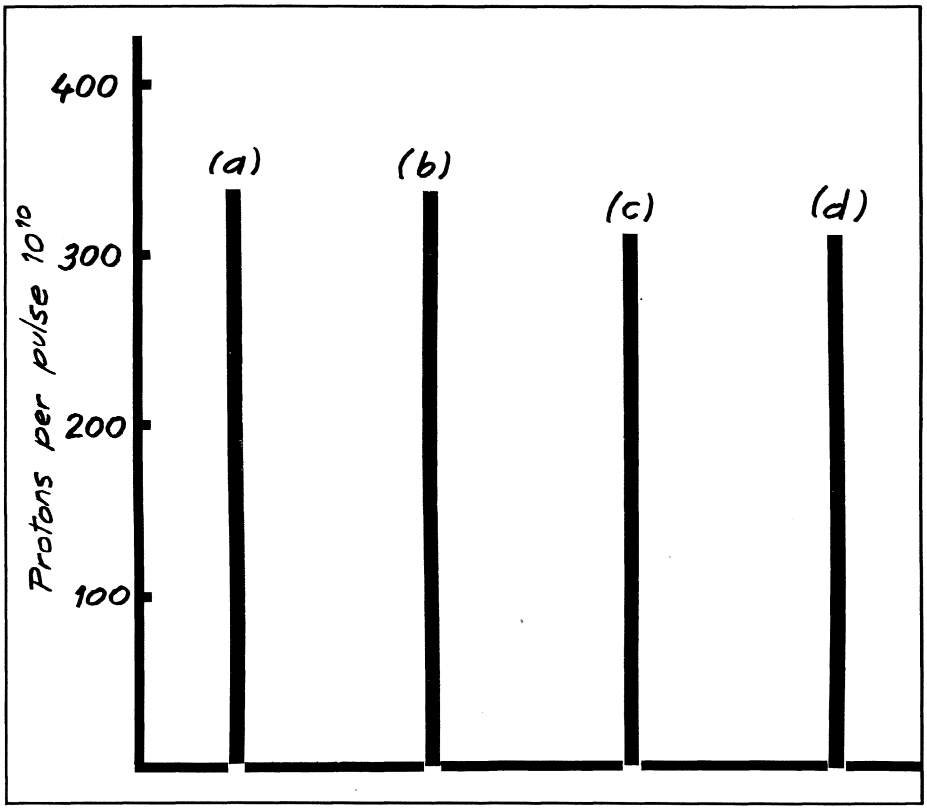
The new beam transport system involves two horizontal bends and a 'goose neck' vertical bend. It comprises a matching section at the beginning to ensure the PS to SPS transition for the beam, followed by a score of quadrupoles which mimic the magnet lattice in the SPS itself. The system is well provided with monitoring devices which were put to good use in an evening of beam studies.

Careful tuning of trim magnets, each with its own monitor feeding position information to better than a millimeter, was carried out. Taking beam profiles in three places with SEM grids (secondary emission monitors) showed that the beam emittance agreed to within 10% with that measured at the output of the PS. Collimator tests proved that the beam diameter was within the expected 2 cm. Powering a skew quadrupole switched the horizontal and vertical phase space of the beam and emittances changed accordingly showing that the beam properties could be turned 90° if this aids injection.

All in all, a series of tests were completed in one evening which traditionally might have absorbed a couple of weeks. This was a result of the beautiful performance of the control system — the computers, the beam monitoring systems and the software. It was most impressive to be able to call up beam properties with such ease, to make changes by feeding the computers simple instructions and to have required information elegantly displayed on the TV screens in a way which was readily absorbed.

The SPS team have many more (and more difficult) jumps to clear before the experimenters get their higher energy particles but they have taken this first jump in such convincing style that it augurs well for the coming months. The first tests to inject and circulate the proton beam in the SPS ring are scheduled for the beginning of May.

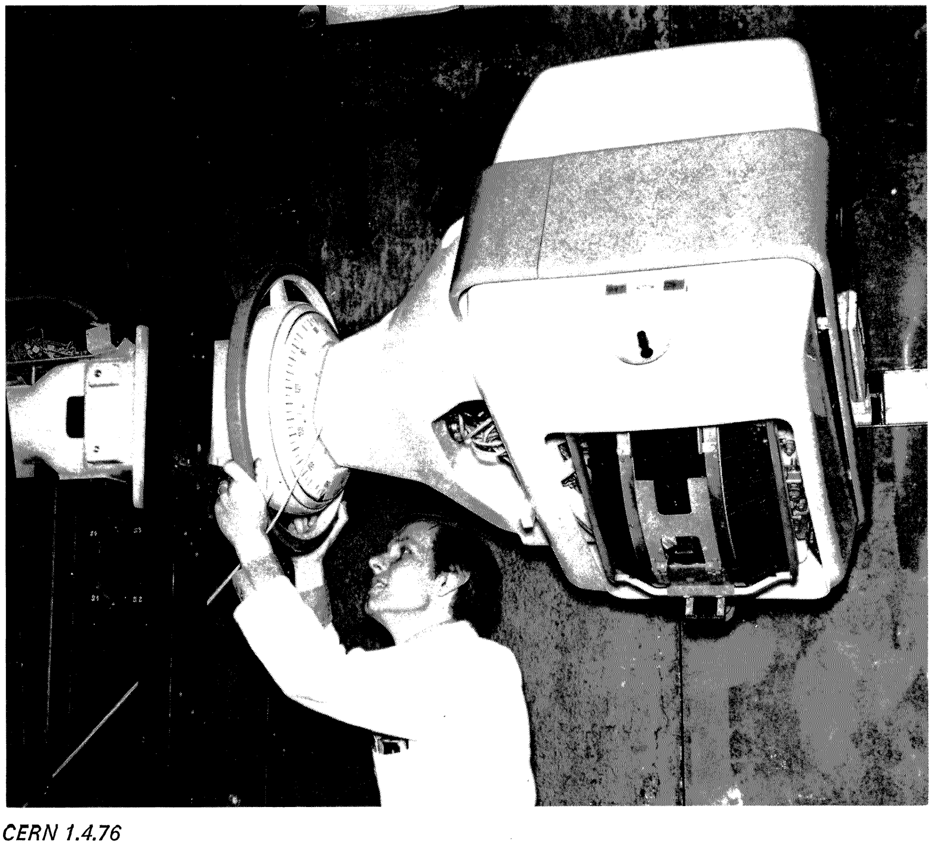




Protons reached the SPS on 5 April. The photograph below shows the beam lighting up the last screen at the end of TT10 close to a temporarily installed beam stop. On the right are beam intensity measurements (a) inside the PS (b) ejected from the PS (c) at the beginning of TT10 and (d) close to the beam dump at the end of TT10. Beam intensities were around 3.5 × 10^{12} protons per pulse and the overall transmission efficiency was over 90%.

PS and ISR have high energy deuterons

On 20 March, the CERN Proton Synchrotron accelerated deuterons to



An 18 MeV betatron from the Hôpital Cantonal de Genève in use at CERN providing particles for tests at the 3.7 m European bubble chamber, BEBC. Gammas emerge from the small window which is towards the bottom of the betatron in the picture. When tests are in progress the machine is swung around to point the gammas at BEBC which is behind the wall in the background.

an energy of 26 GeV and passed them to the Intersecting Storage Rings where they were stacked and stored. Physicists were able to look at high energy deuteron-deuteron collisions. In the same run, the PS also accelerated helium ions (alphas) to 40 GeV. This is the first time ever that deuterons and alphas have been accelerated to such high energies.

The work took place during a Machine Development run and these achievements came without any unforeseen problems arising. The linac and PS ring were performing well within hours of starting the tests and the ISR stacked deuterons at the very first attempt and stored beams for 40 hours. The smoothness of these operations hides, of course, the fact that a number of machine specialists had been spending a fraction of their time preparing for these tests for several months.

They required considerable modifications to linac settings (since the proton-neutron combination in the deuteron is accelerated at only half the rate of a proton), to the magnetic field cycle and to the r.f. cycle in the PS ring (where twice the frequency swing for protons is needed). The ISR also had to reset the delicate r.f. stacking fields to cope with the new particles.

The linac provided 10 mA of deuterons per pulse and the ISR stacked 1.9 A in one ring and 2.2 A in the other. While the ISR were busy colliding deuterons on deuterons the PS ion source changed its deuterium bottle for a helium bottle. 1.2 mA of alphas were accelerated through the linac and 2×10^{10} alphas per pulse through the PS. (There were some difficulties with feedback systems because of the comparatively low intensity of the alpha beam.) A second run at the end of the month pushed the deuteron figures higher. The PS accelerated 5×10^{11} dpp and the ISR had circulating currents of 4.3 and 4.5 A giving a luminosity of about 3.5×10^{29} per cm^2 per s.

Naturally, the physicists at the ISR could not resist sneaking in on the Machine Development run and parasitically taking the first ever high energy data on d-d collisions. Teams were in action at intersection regions I-2 and I-4. As people returned to work at CERN on Monday 21 March they were greeted with a preliminary note headed 'Observation of small angle secondary deuterons produced in deuteron-deuteron collisions at the CERN/ISR'. In most collisions, the deuteron breaks up into its constituents (the proton and the neutron) but in almost a third of them it hangs together. There is more interest in information which can be extracted from proton-deuteron collisions and, during the second run, after eight and a half hours one of the deuteron beams was dumped and 11 A of protons was fed into that ring giving a luminosity of about 1.5×10^{30} per cm^2 per s for ten hours. Data on p-d collisions is now being analysed.

The PS and ISR have demonstrated their light ion abilities in a very impressive way. It will now depend on the degree of physics-interest in deciding how far these abilities should be pushed.

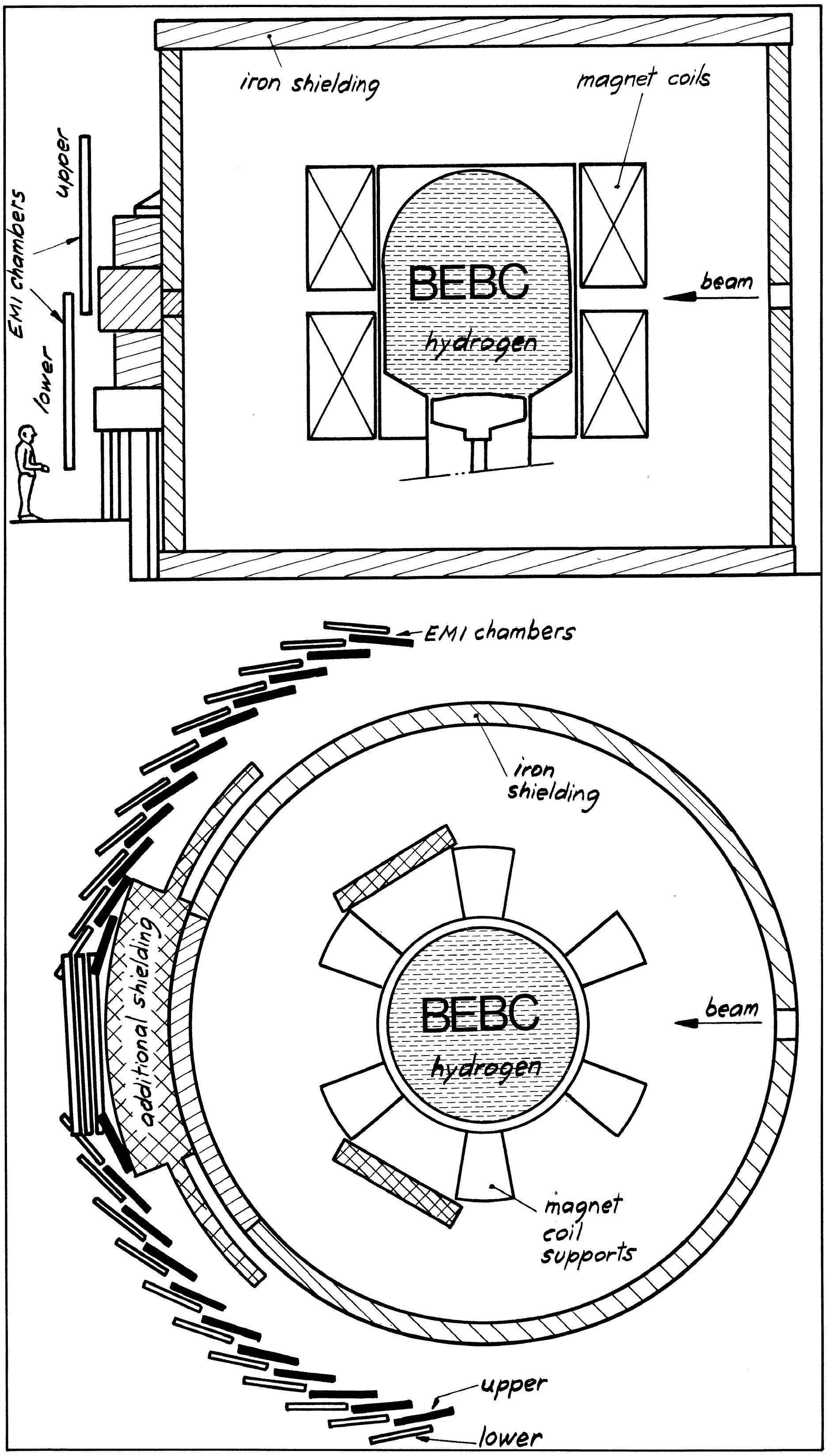
BEBC prepares for 400 GeV

Since the end of January, tests have been under way to prepare the 3.7 m European Bubble Chamber, BEBC, for operation in conjunction with the 400 GeV proton synchrotron (SPS). For these tests a beam is fed to the chamber by a 18 MeV betatron from the Hôpital Cantonal de Genève since the beam line from the 28 GeV (PS) synchrotron has been dismantled to make room for the installation of the SPS beam lines in the West Hall.

The tests are also designed to improve the quality of the photographs. The degree of precision with which the tracks were recorded on photographs during 1975 was already high, but measurement of the tracks by means of the automatic scanning machines has been hampered by a ring of bubbles around the piston and by dust which tends to accumulate on the piston. This problem has been solved by inserting a 2.2 m diameter moving disc at a distance of 50 cm from the piston which masks these bubbles and dust particles.

The SPS will have a relatively slow repetition rate at maximum energy (once every 6 s rather than once every 2 to 2.6 s with the PS). To get maximum physics out of BEBC, one photograph will be taken with hadron beams, produced by 200 GeV protons, and a second photograph with neutrinos, produced by 400 GeV protons, in the same SPS cycle. To do this, BEBC has to double pulse every 6 s within a time interval of 0.7 s. It has proved possible to take a second photograph which is as precise as the first one with an even shorter time interval (0.5 s) between pulses. Tests have also been made at the maximum operating frequency of the chamber with double expansions every 3.6 s and a time interval of 0.4 s. At this high repetition rate there is some turbulence but it can probably be overcome.

Other tests concern the use of neon/hydrogen mixtures and a track sensitive target filled with hydrogen (see February issue, page 48). When hydrogen is used in BEBC, the operating temperature is of the order of 26 K; when mixtures are used, the temperature will be about 28.5 to 29.5 K. The difference does not seem great but it reduces the bubble forma-



Side (above) and bird's-eye (below) schematic views of the External Muon Identifier, EMI, to be installed at the 3.7 m bubble chamber, BEBC. An array of wire chambers are to be located outside the BEBC iron magnetic shield arranged to completely cover a wide solid angle.

tion time by a factor of 3.5. Finer tracks will therefore be obtained, and contrast will be reduced.

Photographs have been taken in hydrogen at 28 and 29 K to check the behaviour of the chamber at these 'high' temperatures and to look at the resulting tracks. No technical problems were encountered and tests with mixtures can safely be envisaged. In April, the internal target was installed in the chamber to be tested initially with hydrogen inside and outside the target and then with a neon-hydrogen mixture. The amount of liquid neon in storage by the end of April will be close on 20 t and regular deliveries are being made at the rate of 1.5 t per month until a total of 60 t has been accumulated.

External Muon Identifier EMI for BEBC

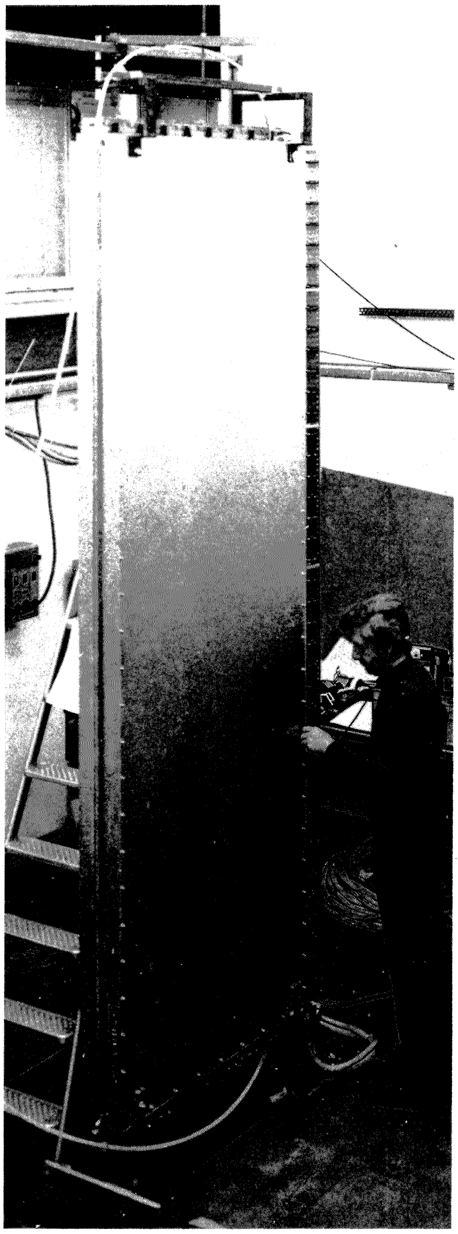
Spotting muons can be of crucial importance in sorting out what is happening in a particle interaction. It is especially true when neutrinos are involved, as any investigator of the neutral current type of weak interaction or any searcher for charmed particles will readily testify. This is why an External Muon Identifier, or EMI, is being built for use in association with the 3.7 m European bubble chamber, BEBC, when it comes into action towards the end of this year receiving beams (mainly neutrinos) produced by the 400 GeV proton synchrotron.

The first problem is that the simple absorption method of distinguishing a muon cannot be applied. A muon passes through matter much more readily than other particles, with the exception of the neutrino itself, and it can be identified with a high degree of confidence by putting enough matter in front of a particle. If it gets through, it is a muon. This is a feasible method of detection at modest energies (see for example the description of the PLUTO spectrometer at DESY, page 139) but when there are other particles at high energies and when neutrino beams are being used, a variant of the simple technique is needed. BEBC is already surrounded by an iron shield and more iron is being added. Muons still have a high probability of getting through this amount of matter with very little scattering; other high energy particles from the neutrino interactions in the chamber, however, might also get through. Even more troublesome is the high background from muons produced elsewhere and from neutrino interactions in the iron.

The technique is to use the fact that other particles are either absorbed or very likely to be strongly scattered in the iron and that neutrino interactions in the downstream iron leave no tracks in the bubble chamber. If it is possible to reconstruct the trajectories of the particles, using the photographs of BEBC together with position signals from the EMI, it can be worked out whether the EMI is spotting a muon from a neutrino interaction in the chamber or a particle from some other source. The EMI has therefore to give reasonable (from 0.5 to 3 cm) information on particle position. This technique has already been used in the EMI at the 15 foot Fermilab chamber.

A second problem also concerns the high background. The EMI has to be switched on to catch muons all the time that BEBC is sensitive (for the 2 ms pulse length during which tracks can be formed in the BEBC liquid). A neutrino interaction is likely to occur in the liquid about once every four pulses and it is only then that the muon needs to be seen. However, in the course of seeing this one muon from a neutrino interaction, the EMI will unavoidably record many hundreds of other charged particles (from interactions in the shielding, cosmic rays, etc...). All this information has to be stored so that the muon can be dug out later when studying the bubble chamber pictures.

One of the 3 m × 1 m wire chambers built for the EMI using special construction techniques. Test installation of the first chambers at BEBC took place at the beginning of April.



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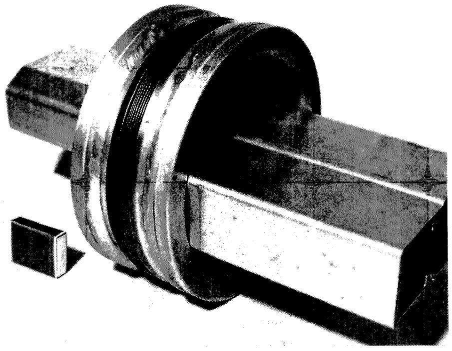
There is in fact too much data coming from the EMI during the 2 ms pulse for it to be fed directly onto magnetic tape. A 'buffer' is being interposed to collect the data at the necessary fast rate during a pulse and to spill it more slowly onto tape between pulses. Much of this background information could be cut out if there was some way of pinpointing the time within the pulse at which the interesting interaction occurs. There are some ideas now being tried which might help but none of them are adequately tested up to now.

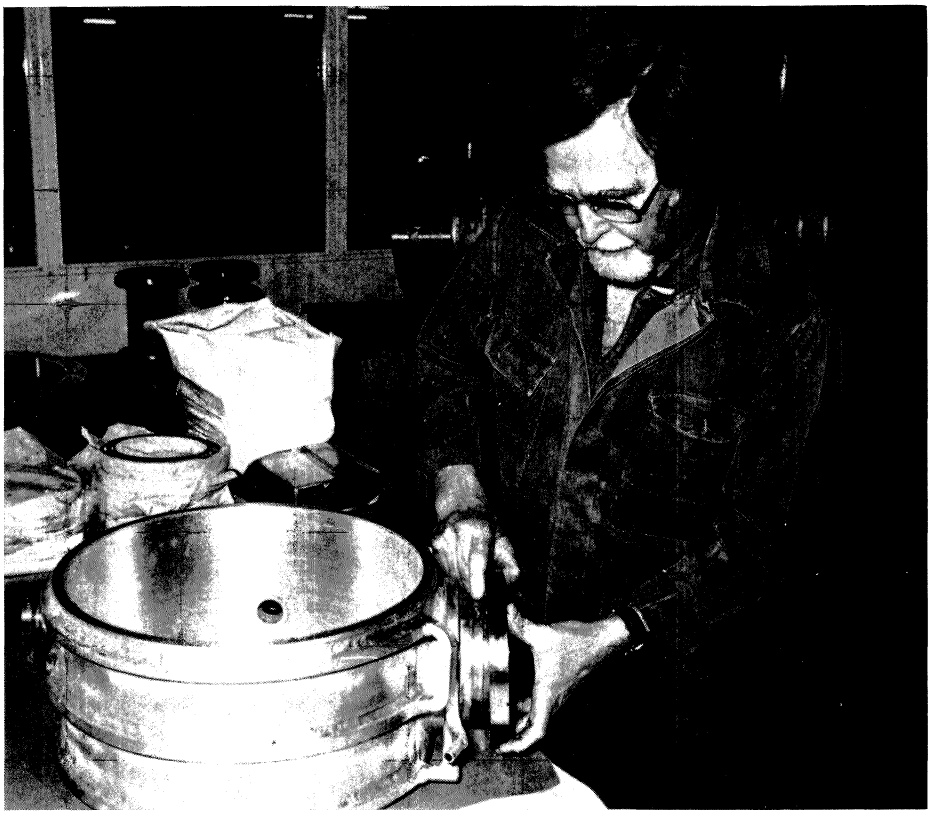
The third problem is that the EMI detectors are some distance from the interaction region in the bubble chamber. Obstructions make it necessary

'Transition section' between two pieces of vacuum chamber for the PETRA electron-positron storage ring. The aluminium chambers are welded to stainless steel bellows using a new welding technique, known as DEPI, developed at DESY.

The first successful application of the DEPI aluminium- to-stainless steel welds has been in the fabrication of the prototype r.f. cavity sections for PETRA.

(Photos DESY)





to install them outside the iron shield and, in order to completely cover a big opening angle from the interaction region, the detectors have to cover a very large area. The chambers also have to conform to hydrogen safety rules.

The way in which these problems are confronted in the EMI is by building a wall of proportional wire chambers 6 × 25 m^2. The wall is made of two rows of chambers, one on top of the other, each 3 × 1 m^2 arranged with the chambers slightly overlapping (6 cm) so that there are no holes for particles to slip through undetected. This concern to avoid holes also dictated a special chamber construction technique, which avoids the use of large frames or support lines (to hold the wires in position very precisely) by using a honeycomb structure between the planes. It proved possible to produce and hold wire planes accurate to 0.1 mm without large frames and since these successful tests, the use of honeycomb structure for wire chambers has grown rapidly in popularity. Altogether the EMI has 75 000 wires and 10 000 cathode strips. To reduce cost and complexity, wires are linked in groups to a single electronic channel depending on the space resolution requirements in different parts of the detector. Ar/CO_2 gas mixtures are used in the chambers since they are cheap, easy to use and, above all, safe.

Signals are collected via 20 000 channels. If the buffer had to record signals from every channel each time a charged particle caused a hit, it would have to be very large and expensive. A two stage idea avoids this and greatly reduces the cost of the electronics. Each chamber is linked to a small buffer (40 bit/channel) which reads the chamber wires when a hit occurs in that chamber. The main buffer (1024 bit/channel) then needs to know only that a chamber has been hit rather than a wire and can interrogate the buffer of the chamber to identify the wire.

A test installation of two of the wire chambers was made behind BEBC at the beginning of April and they are being left in place for the next technical run of the bubble chamber to ensure that there are no problems due to vibration. Some of the extra iron absorber is installed. The wire chambers are being produced at a fast rate (up to one a week) and it is hoped to begin their definitive installation in September and to have the full wall in place by the end of the year.

DESY

Διμεταλλική 'Επικόλλησις

Since last summer, work has been in progress at DESY attacking the problems of ultrahigh vacuum transition sections between aluminium alloy and stainless steel. These sections are needed for the vacuum system of the electron-positron storage ring, PETRA, which is essentially composed of extruded aluminium chambers and stainless steel bellows, flanges and feedthroughs. Approximately 1300 transition sections with diameters ranging from 20 to 200 mm are required to join the stainless steel components to the chamber.

The commonly used explosion bonded aluminium-stainless steel plates are expensive and limit freedom in designing the vacuum chambers. To overcome these disadvantages, a novel technique has been developed at DESY to obtain a bakable, ultrahigh vacuum joint by argon-arc welding aluminium alloys to stainless steel. The technique has been named DEPI (from the Greek) Διμεταλλική 'Επικόλλησις meaning bimetallic welding or brazing. For this joining method, the stainless steel components have to be preplated in the weld area with different metallic thin coats to avoid the formation of brittle aluminium compounds during the welding process. The necessary adherence of these coats to the steel matrix is obtained by heat-treating in vacuum and also in an inert gas atmosphere. The treated stainless steel components can then be joined to aluminium alloys by

Mounting cylindrical wire chambers for the PLUTO spectrometer. Close examination of the cylinders reveals the different orientations of the detecting strips enabling all the desired coordinates of the charged particles traversing the cylinders to be picked off from the different planes.

using the normal a.c.-inert gas welding technique for aluminium.

The cost of DEPI welds is only slightly higher than for comparable aluminium welds and substantially lower than for the explosion bonded technique (by a factor of 2 to 7 depending on the diameter). The main technical advantage is the greater freedom in the design of the vacuum components. The length of the typical transition section for the PETRA vacuum chambers, including the bellows, has been reduced to 110 mm thanks to using this method.

Many DEPI welds with diameters up to 200 mm have been intensively tested and have shown excellent performance. The samples were subjected to forty heat cycles up to 350°C. During the cycles the welds were thermally shocked with cold water while the samples were at temperatures of 150 and 350°C, respectively. Other samples were subjected to thermal shock from 200°C to liquid nitrogen temperatures and showed no damage. Mass spectrometric measurements revealed no changes and the welds remained leak-tight to better than 10^{-10} torr l/s. The desorption rate of the welds is also very low and is determined predominantly by the desorption rate of the stainless steel surfaces.

Mechanical tests on the welds have shown that the joints have rupture strengths of up to 120 N/mm^2, which is slightly lower than the strength of the normal aluminium-aluminium welds. The first successful application has been in the fabrication of the PETRA prototype r.f. cavities.

Another bonding method, known as friction-bonding, was also improved at DESY by using the same coating technique (called REPI from the German 'Reibschweissen'). The bonding strength approaches the strength of the aluminium alloy. Due to inherent fabrication limitations in the geometry and configuration of the parts to be joined, the REPI welds will only be used in the PETRA vacuum system for joints carrying high mechanical loads.

In general it seems feasible that joints of other pairs of material can be realized by using the DEPI method if more work is put into the development of the technique.

PLUTO spectrometer

The DORIS electron-positron storage rings at the DESY Laboratory, together with SPEAR at Stanford, have been major sources of information on the heavy stable particles at 3.1 GeV and 3.7 GeV and their relatives. At DORIS there are two beam collision regions — one occupied by the DASP detection system (see December issue, 1974) and the other by the PLUTO spectrometer.

PLUTO surrounds the interaction point with cylindrical detectors, leaving only the beam pipe free where the positrons and electrons collide in ultrahigh vacuum at the centre of the detection system. A magnetic field, parallel to the cylinder axis, is produced by a superconducting solenoid coil of 1.6 m diameter. The coil is enclosed in a cryostat supplied with liquid helium via a chimney on top. The current in the coil can be raised to 1260 A to give a field of 2 T, concentrated in a volume of 1.4 m diameter and 1 m length inside the cryostat and shaped to give optimum homogeneity by an iron yoke, which also carries the magnetic return flux. The field on the beam axis causes serious disturbance to the orbiting beams and this has to be countered by superconducting compensating coils producing an equal but opposite field on the axis.

Having the large volume magnetic field makes it possible to measure the momenta of the charged particles

The PLUTO spectrometer on the DORIS storage ring at DESY. The two halves of the magnet yoke are drawn back revealing the cylindrical cryostat containing the superconducting coil cooled with liquid helium via the chimney above.

(Photos DESY)

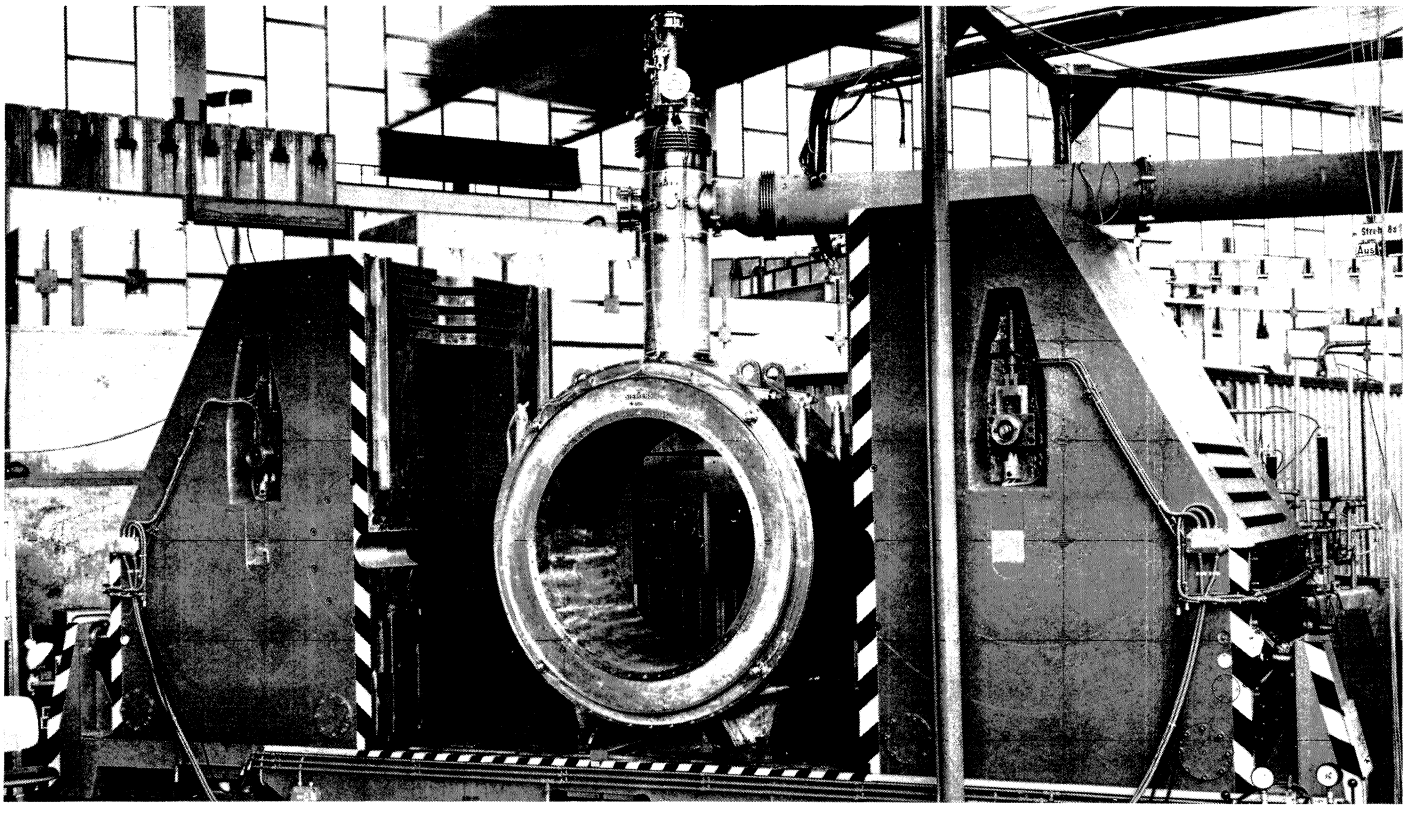
emerging from the interactions. The inner volume of the cryostat is filled with a system of thirteen cylindrical detection chambers on increasing radii. Some of the cylinders are made with copper foil cut into stripes at 45° or 90° with respect to the axis to give independent coordinates of particle positions. Other cylinders have 30 μm diameter tungsten wires running parallel to the axis.

Such a large system of cylindrical multiwire proportional chambers has special problems. The mechanical accuracy required in all dimensions is 0.2 mm, which is a relative precision of 3×10^{-4} for the largest chamber in PLUTO. The whole system has 7600 wires and 2760 stripes. The chambers are filled with a gas mixture of argon, propane, and methylal and work with a negative voltage applied to the stripe surfaces, the wires being at ground potential. The passage of a charged particle initiates a tiny charge deposit on the nearest wire and stripe on the cylinders causing an electric signal in one member of each coordinate system. These signals are amplified and their coordinate numbers, from all chambers, are transferred to a computer, which can analyse and reconstruct the track of the particle. A picture can be displayed on a screen immediately after the event has been taken.

Events from electron-positron collisions have a large fraction of neutral particles which mainly decay into photons. To detect these, two lead cylinders are inserted in the sequence of chambers, one at a medium radius with 2 mm thickness and another in front of the outer two chambers with 9 mm thickness. In the lead, photons are converted into an electron-positron pair which can be detected. By scattering and shower production in the lead, both cylinders are also very effective in helping to distinguish electrons from pions and heavier particles. The lead cylinders cover 56 % and 65 %, respectively, of the full solid angle 4 π for the detection of neutral particles. For charged particles, however, PLUTO is a 4 π spectrometer in a very close approximation because the chambers cover 93.5 % of the full sphere around the interaction region.

Muons can travel without interaction through thick layers of material such as the iron yoke of PLUTO, which has a thickness of 50 cm of iron. Thus, for identifying these particles, the outside surface of PLUTO is covered with 50 m² of flat proportional tube chambers, covering 50 % of 4 π. A track detected in the cylindrical detector inside the yoke is extrapolated through the iron to the outer detector to see if there is a signal from a penetrating muon.

Altogether, the detection system has 14 860 signal channels organized in amplifier cards of 30 channels each.



The high energy end of the 800 MeV proton linear accelerator, LAMPF, at Los Alamos. The full experimental programme at the accelerator has opened up again, after 'the great shutdown', with beams in the meson area. The side-coupled cavities seen in the photograph are now in widespread use in clinical applications. The sales of such machines exceed the cost of LAMPF itself.

(Photo Los Alamos)

An event is triggered by an electronic logic, which combines the wires of cylindrical chambers in a scheme of fast coincidence and thus recognizes track segments. The event pattern is preanalysed within 30 μs and criteria can be applied to reject tracks coming from some of the beam-gas interactions or from cosmic rays. Only those events which fulfill the criteria are transferred to the on-line computer. After a more refined analysis in the on-line computer, accepted events are sent to the central computer of DESY, which generates event displays, statistics and analyses of the detector functions. Finally the events are stored on magnetic tape and analysed for tracks. All this takes only 1/100 of a second for each event. But the time needed to squeeze out new physics from the data is a few orders of magnitude larger!

The interaction region at DORIS, where PLUTO is reinstalled, was occupied until the end of 1975 by the Heidelberg-DESY experiment, which discovered the X (2875) state by observing its two photon decay with a non-magnetic detector. PLUTO will now investigate the higher energy region between 3.9 and 4.4 GeV in the centre of mass, particularly looking for electron-muon pairs from possible charmed states or heavy leptons. After a few test shifts, DORIS coped well again with the PLUTO field disturbance at the higher energies.

LOS ALAMOS
Protons in meson area again

On 17 March, the 800 MeV proton linear accelerator, LAMPF, at the Los Alamos Scientific Laboratory moved closer to resuming full operation after 'the great shutdown'. Protons were taken again into the main experimental hall, the meson area, and tests began on the meson beams.

During the great shutdown, which occupied most of last year, the accelerator had a major wash and brush up in an attempt to clear the problems which were limiting peak performance (see October issue 1974). LAMPF's most exceptional design parameter is the output beam intensity of 1 mA consisting of 900 μA of protons and 100 μA of negative hydrogen ions. This figure is ten thousand times higher than had been obtained at LAMPF energies from the preceding generation of cyclotrons. However, to approach this level of operation will be a long struggle in mastering beam behaviour so as to hold radiation levels down.

Since the great shutdown, it has been possible to accelerate 100 μA with less stray radiation than had previously been experienced with an intensity of 10 μA. In fact peak currents of 200 μA have been accelerated but under conditions which were unacceptable from the point of view of radiation.

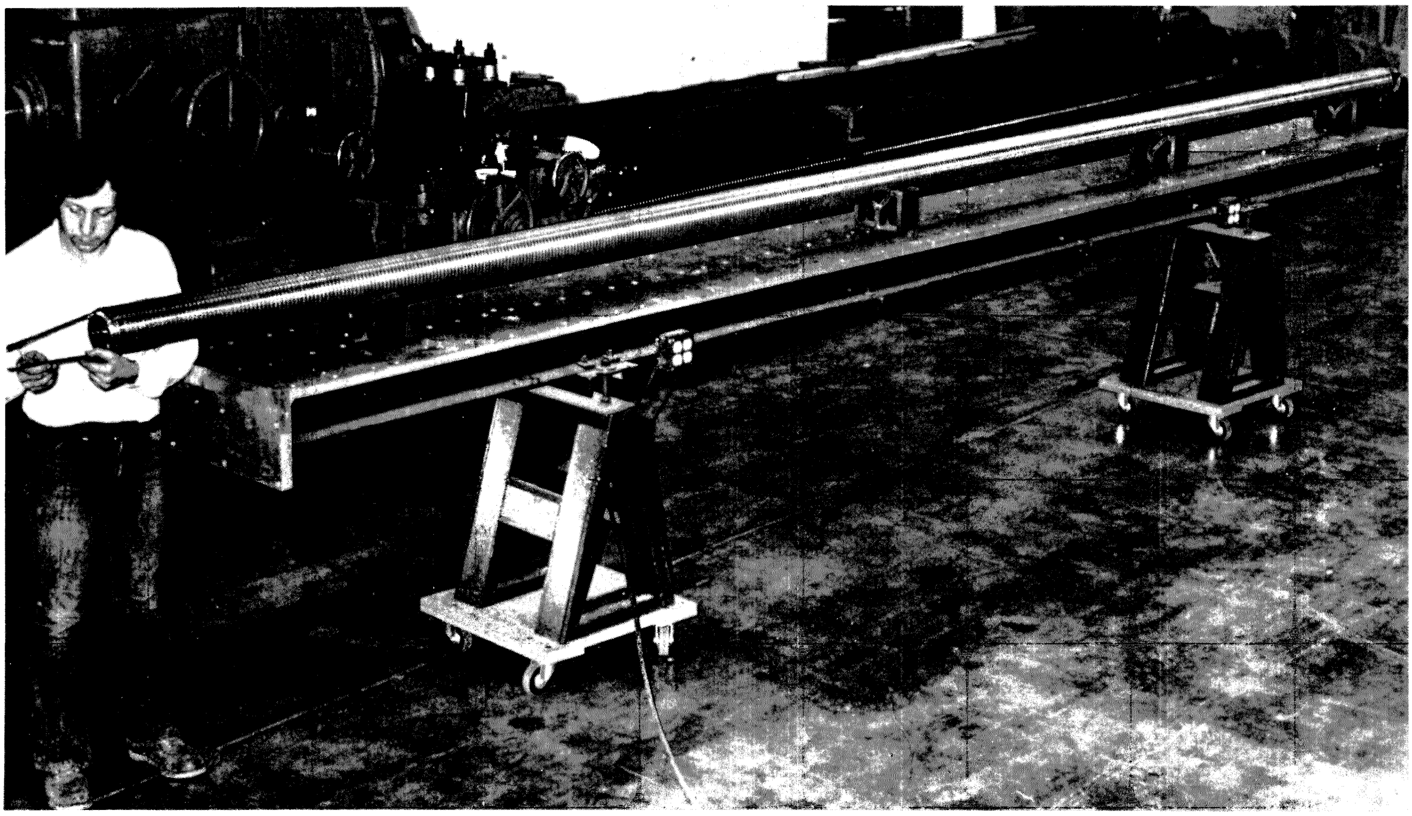
In the March tests protons were taken into the meson area for the first time for over a year (apart from a short checkout in February) and the full research programme is opening up again. It is hoped during the next six months to increase the standard operating current from 10 to 100 μA.

Accelerator performance has been steadily improved since it came back on the air last August after the shutdown. Reliability is much better and dual beam operation (acceleration of protons and negative ions simultaneously) has been achieved. Some research has been under way since October but experiments have been limited to the neutron and proton areas while preparations for higher intensity beams were completed in the meson area.

Technology Liaison Office

A Technology Liaison Office has been established at Los Alamos with Gene Stark as head. The Office will be actively involved in the business of 'technology transfer' — trying to get the techniques which are evolved in the course of scientific research known to industry where they may have applications.

At national level, ERDA has several posts which are concerned with technology transfer. One is the Director of the Office of Industry, State and Local Relations (Farewell Smith); another is the Assistant Director for Technical Information (Ed Stokely). The Los Alamos move reflects the same concern at Laboratory level. Other Laboratories have had similar posts for some time, for example



Brookhaven set up an Office of Technology Transfer (under William Graves) in 1974.

Los Alamos has a lot of technology to transfer; several developments in recent years are major commercial successes. One of them arose in designing LAMPF. The higher energy end of the machine is built of side-coupled cavities which were developed by Ed Knapp, Darragh Nagle, Bruce Knapp and Jim Potter. They are already in widespread use in clinical X-ray and radiography equipment. More than 350 such machines have been built (at a cost of $150 000 or more) involving sales which have exceeded the cost of the LAMPF accelerator.

Another winner is a heat pipe technique invented by George Grover to transfer heat in satellites. By varying the fluid in the pipes they can cope with temperature ranges from 0 to 2000° C. The idea is already used in recovering heat from furnace flue gases. It will be used to prevent temperature rises on the Alaska oil pipeline and even threatens to be used to convey heat to the centre of roast beef to reduce cooking time in domestic cooking appliances (an example of the misuse of technology to commit a culinary crime).

Los Alamos is also heavily engaged in energy programmes. There is work on the applications of superconductivity. At LAMPF, medical applications include isotope production and cancer treatment with negative pions. The Technology Liaison Office is likely to be a busy place.

BROOKHAVEN BLIP and CLIF and MEIN

The 200 MeV linac at the Brookhaven 33 GeV Alternating Gradient Synchrotron has a superfluity of protons compared with what is needed for the AGS itself. It can accelerate 10 pulses/s with 50 mA per pulse and 200 μs pulse lengths while the AGS needs only one of these every 2 s. Built into the linac design was the intention to make use of the extra protons. The proton beam parameters (energy, intensity and pulse length) are variable.

For several years now, the Brookhaven Linac Isotope Producer, BLIP, has taken some of the protons and used them to produce large quantities of radionuclides for applications in biological research and nuclear medicine. The protons can also be deviated to a Chemistry Linac Irradiation Facility, CLIF where thin targets are irradiated and taken pneumatically to a laboratory for chemical separation and spectroscopy on the products.

CLIF has been used mainly for the study of neutron rich nuclei in the hafnium region. The incoming proton dislodges two protons from the nucleus leaving a nucleus behind with an excess of neutrons compared to the target nuclei. These investigations are sometimes blurred because neutrons can also be dislodged from the nucleus and irradiations from the two types of isotope can interfere. A way around this is to irradiate the target with neutrons rather than protons.

This led to the setting up of a Medium Energy Intense Neutron facility, MEIN. Here the full intensity proton beam is fired into a water-cooled copper beam stop to yield a neutron beam. A flux of neutrons of over 10^{11} neutrons per cm^2 per s emerges in the energy range 25 to 200 MeV (the spectrum is almost constant between 30 and 160 MeV). It has been used to produce neutron rich isotopes which can then be studied under more favourable experimental conditions.

One of the early successes was the production and study of a new iron isotope, ^{62}Fe with a 68 s half-life, from the neutron irradiation of a nickel foil. At the Washington Meeting of the American Physical Society, 22-29 April, the identification and study of several other isotopes are being announced. They are the tungsten isotope, ^{190}W with a 35 min half life, an osmium isotope, ^{196}Os with a 35 min half life, and a radium isotope, ^{230}Ra with a 93 min half life. These are the most neutron rich isotopes of these elements yet produced.

The first 22 foot magnet to be made on the new production line for the Fermilab Energy Doubler. It achieved almost 4 T in its tests and the addition of an iron yoke should give the 4.5 T required for 1000 GeV operation. Eight hundred of these magnets will be needed to complete the Doubler ring.

A full-scale model of the Main Ring tunnel at Fermilab showing the newly decided location of the Energy Doubler magnets threaded through the stands of the existing magnets. The closer proximity of the rings will ease the problems of colliding the two beams.

(Photos Fermilab)

The research has been carried out by P.E. Haustein, S. Katcoff, E.M. Franz and J. Giliat of Brookhaven, T.F. Ward and H.A. Smith of Indiana University, N.A. Marcos of Squibb Inc., J.C. Hill of Iowa State University and R.F. Petry of the University of Oklahoma.

FERMILAB

22 foot Doubler magnet operates

On 12 March, the first 22 foot bending magnet from the new production line turning out magnets for the Fermilab Energy Doubler/Saver reached 4.4 kA on the first quench and by the thirteenth quench was providing a field of 3.95 T, 97 % of short sample. The test was carried out in a slanted cryostat with boiling helium for coolant. The magnet is of banded construction and did not have an iron yoke for this test. Addition of the yoke will raise the field to 4.5 T which corresponds to Doubler operation at 1000 GeV.

The Doubler production factory came into action on 20 January and the first magnet came off the line in early March. The line is now producing magnets at the rate of one a month and this rate will be increased steadily as magnets are installed in the ring.

Future doubler magnets will be 'collared' rather than banded. The collar, a jigsaw assembly of two stainless steel laminates, provides much greater strength than the banding. Studies with strain gauges on banded models show that the training phenomenon is associated with permanent deformations of the magnet. The collar will substantially reduce these deformations and, at the same time, it will allow the magnet aperture to be increased. A 1 foot collared version has been built and tested.

The location of the Doubler in the main ring tunnel has been changed. It has moved below the present magnets so that the two beams are now only 18 inches apart vertically and aligned horizontally. The Doubler will thus thread between the existing magnet stands. This new arrangement puts the beam in the Doubler substantially closer to the present accelerator beam. It will make beam manipulation much easier if collisions between the two beams are called for at some time in the future.

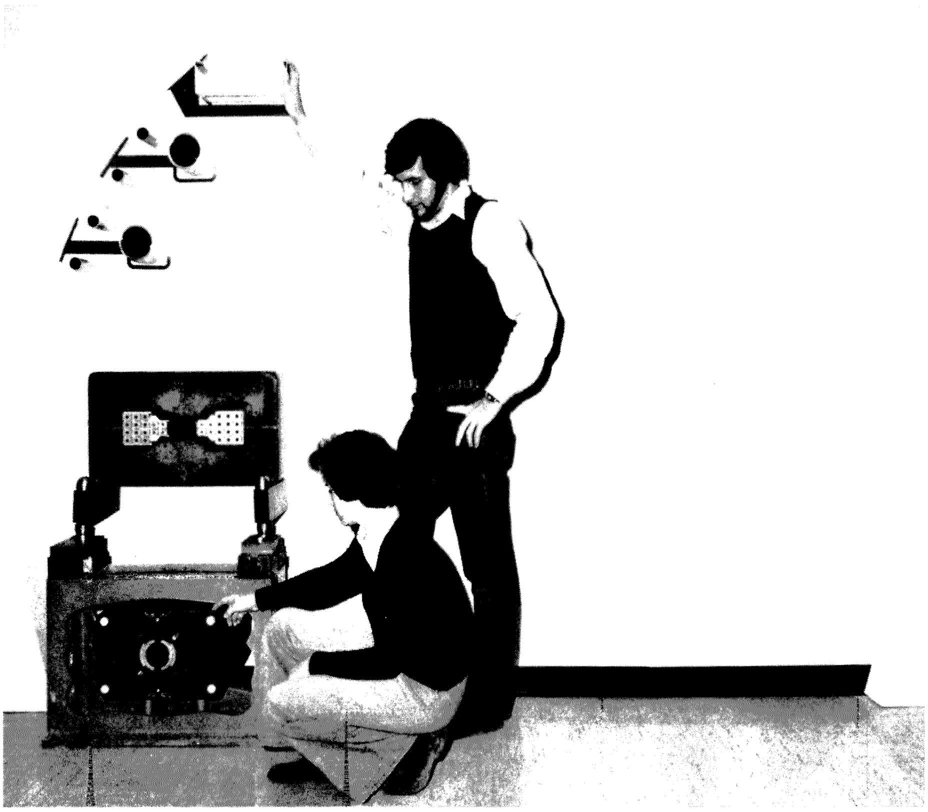
RUTHERFORD

Compumag Highlight

Highlight of the recent Compumag Conference on the Computation of Magnetic Fields, organised at Oxford University by the Rutherford Laboratory, was a specially set-up magnet design work station. Based on a GEC 4080 computer linked to the Rutherford Laboratory's main IBM 360/195 machine, the work station enabled delegates to use Rutherford's GFUN magnet design software running on the IBM computer together with additional computer-aided design programs running on the GEC machine. Teams from CERN, Imperial College London, and Rutherford demonstrated the capabilities of the magnet design systems.

Magnet design work began at Rutherford as part of the high energy physics programme but its potential for applications in other fields was soon realised and the GFUN software has now been used by a number of other organisations and research centres for applications in such fields as magnetic levitation and Tokamak magnets for fusion experiments.

The ability of the GFUN program to predict magnetic fields to 1 part in 10^4, confirmed by measurements of



the prototype magnet for the EPIC project, demonstrates the usefulness of the software in the design of high precision magnets for HEP experiments. A version of GFUN is used at CERN where it has assisted in the design of bubble chamber magnets and of quadrupoles for the ISR.

The Conference attracted 210 delegates from 15 countries and brought together experts from industry and universities as well as other research centres. Topics covered included magnetostatics, magnetic materials, steady state and transient eddy currents and computer aided design, while applications described included high energy physics, fusion studies, electrical machines and magnetic levitation.

The Compumag international steering committee is to meet in the near future to decide on the location of the next Conference, scheduled for 1978.

ARGONNE
Pellet fusion with heavy ion beams

A new concept in fusion, which could result in an accelerator-based thermonuclear energy source, has been advanced by Richard Arnold and Ronald Martin of Argonne in a paper submitted for publication in the journal Nuclear Fusion.

Generation of energy from the thermonuclear fusion reactions could be accomplished in a pellet of deuterium-tritium mixture which is compressed and heated by a sufficiently powerful external source of energy. Arnold and Martin have calculated that the necessary power levels can be obtained if storage rings containing multi-GeV circulating beams of heavy ions are used. The ion beams would be stored over a period of a second, then extracted and focused on a 1 mm diameter pellet in a few nanoseconds.

The use of relativistic heavy ions is particularly attractive, in comparison to other proposed fusion technologies, since a research and development programme of only a modest scale and of limited scope seems to be required before design and construction of a major facility could be envisaged. The goals of such a pellet fusion storage ring facility would be to demonstrate 'breakeven' (when the fusion energy release is equal to the ion beam energy in the storage ring), and to test high-gain pellet designs which could yield substantial net energy production.

The ion beam energy necessary for breakeven using 10 MeV protons has been estimated by M.J. Clauser in Physical Review Letters 35, 848 (1975). The figures can be applied to heavy ion beams of the same range. Iodine ions, which are suggested as an appropriate species, have a suitable range (0.2 mm in a metal shell) with an energy of 8 GeV. This figure has been used in the fusion facility conceptual design, which consists of a conventional rapid cycling synchrotron, a storage ring to hold 16 A of 8 GeV iodine ions filled in 0.5 s and a hundred beam transport channels which focus 8 ns pulses of extracted ions from each channel simultaneously on a 1 mm pellet. Extraction would be accomplished through the use of stripper foils.

Some specific questions, for example concerning achievable vacuums and ion-ion collision cross sections, must be settled before engineering design can proceed. However, these questions can probably be resolved in two or three years, if sufficient effort is applied. Construction of a fusion facility would be comparable to that of a major high energy accelerator, and might take five to six years.

People and things

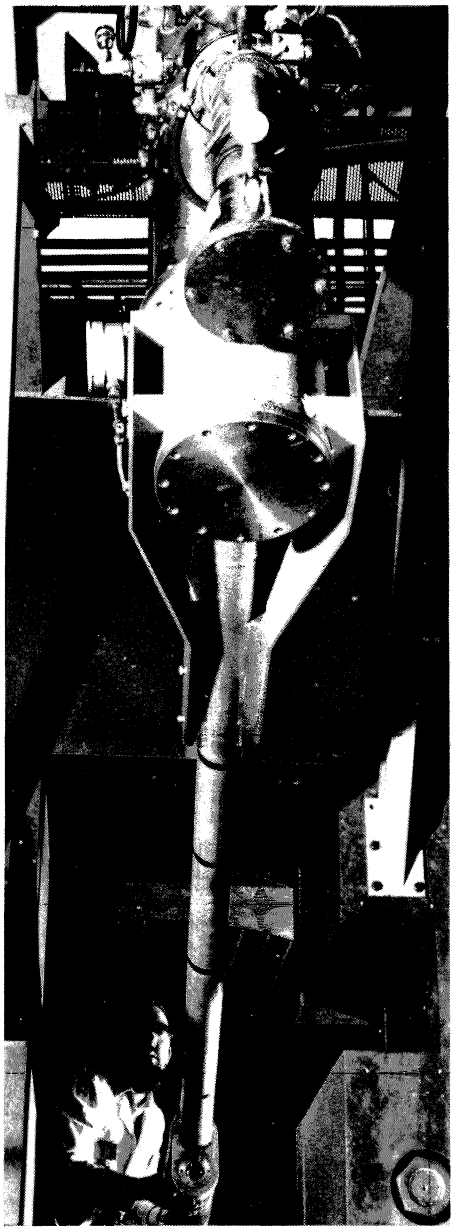
FRS for Gerry Pickavance

It was announced in March that Dr. Thomas Gerald Pickavance, C.B.E., has been elected a Fellow of the Royal Society — one of the highest science honours in the UK. The citation reads, 'Distinguished for contributions to the design and construction of accelerators for high energy physics and for his exceptionally effective direction of the Rutherford High Energy Laboratory'. Gerry Pickavance was the first Director of Rutherford during the years when the Nimrod proton synchrotron was built. He did much to develop the relationships with the physicists in the Universities and to establish the mechanisms for them to use a national research facility efficiently. He contributed greatly also to the European scene and was Chairman of the European Committee for Future Accelerators, ECFA. He suffered a severe stroke in 1971 which caused his withdrawal from active work but by now he has picked up most of the threads of a normal life again. His many friends will be delighted at this additional tribute to his contributions to high energy physics.

Polarization at KEK

At the National Laboratory for High Energy Physics, KEK, in Japan, they

Below: Aligning a liquid hydrogen target in the Rutherford Multiparticle Spectrometer (RMS). The big magnet was previously used in the Rutherford 1.5 m bubble chamber and is equipped with capacitative readout spark chambers and multiwire proportional chambers. A high pressure Cherenkov, designed at Daresbury and completed at Rutherford, will distinguish between pions and kaons above 1.35 GeV/c. The RMS will first study $\pi^+ p \rightarrow K^+ \Sigma^+$ *in the resonance region using the hydrogen target. A frozen spin target is being developed based on a design by T. Niinikowski used at CERN. This should be capable of proton polarisation of more than 90 %.*



Al Lisin has succeeded John Voss as head of the SLAC Mechanical Engineering Department. Al is pictured here examining the tuning end of a SLED unit. He has worked on the superconducting accelerator design study, PEGGY, SLED and PEP. John who spent some time at CERN on the ISR vacuum system, was project engineer on SPEAR. He has now moved to Varian.

(Photo Joe Faust)

have been developing polarized targets which will be provided as standard experimental facilities to the experimenters. One aim is to build a frozen target (where the target is polarized in a strong magnetic field and then moved, with the spins 'frozen', to another magnetic field which has a wider aperture for the emerging particles to escape to detectors). A helium 3 — helium 4 dilution system is used for refrigeration. Deuteron polarizations as high as 18 % have so far been achieved, not far short of the theoretical value of 25 %.

100 mA of negative hydrogen ions

Tests of a negative hydrogen ion source for use at the Fermilab 400 GeV proton synchrotron have been completed at Brookhaven. The source will be installed at Fermilab with the intention of increasing the beam intensity in the 8 GeV booster by means of change exchange injection. A current of 100 mA of negative ions was achieved from a magnetron type source. Krsto Prelec and Theo Sluyters are leading the Brookhaven work and were assisted by Cyril Curtis and Charles Schmidt from Fermilab. Prelec and Sluyters are now interested primarily in producing several amperes of negative deuteron ions for use in neutral beam injectors of fusion devices.

Conferences

The 1976 Summer School in Health Physics (Radiation Protection) will be held at Imperial College London from 21 June to 2 July. It is aimed particularly at graduates in science, engineering or medicine who need a broad basic knowledge of the subject of radiation protection. Further information from Dr. H.D. Evans, Senior Lecturer in Health Physics, Imperial College, London SW7 2AZ.

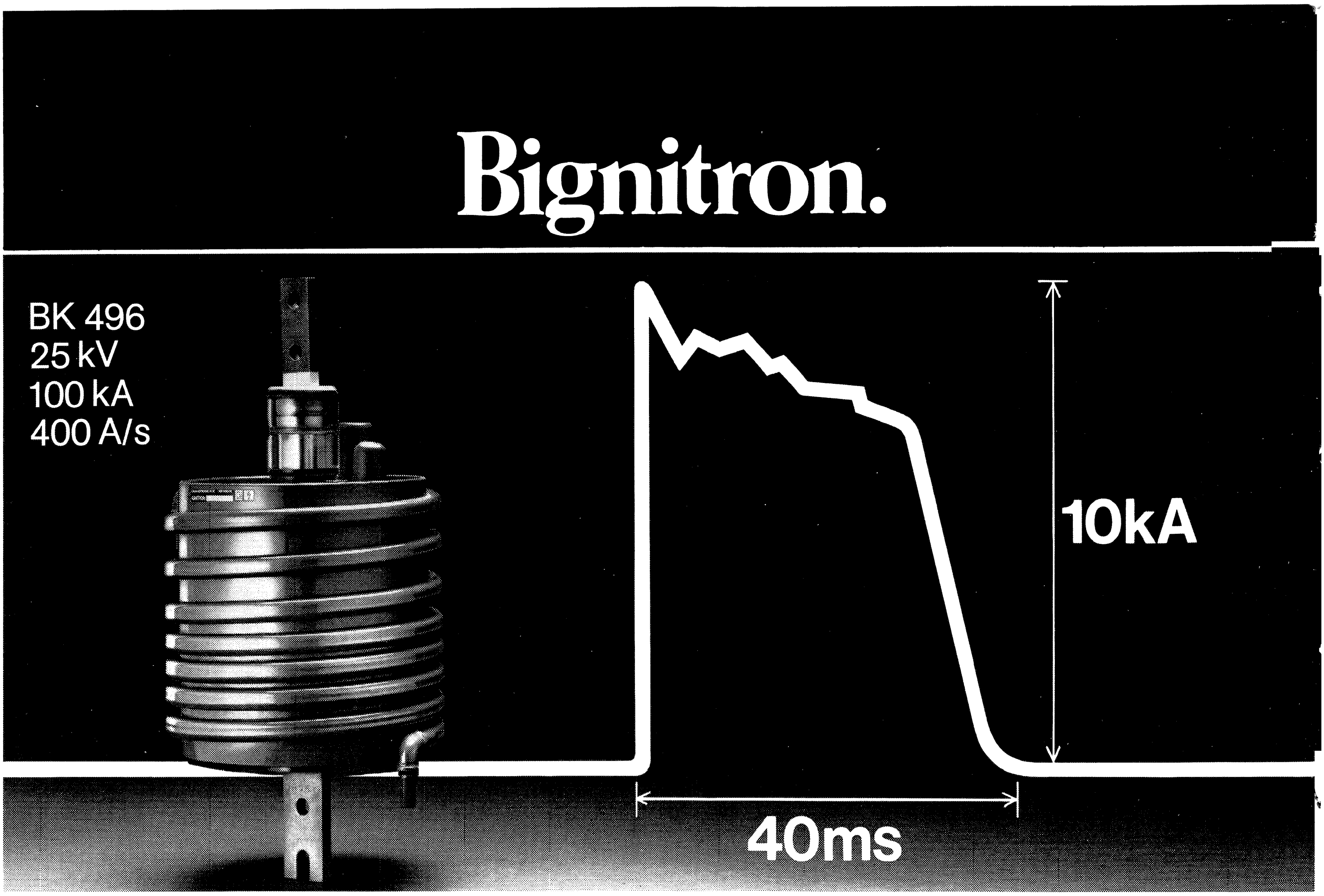
The 1976 PEP Conference will be held at SLAC from 23 June to 25 June to review the development of detectors and experiments for the PEP electron-positron storage ring. Further information from PEP Conference Secretary, Building 47, Lawrence Berkeley Laboratory, University of California, Berkeley CA 94720.

ISABELLE for neutrinos also?

John Humphrey at Brookhaven, prompted by Barry Barish, has looked at the possibility of storing muons in one of the ISABELLE rings. The experimental interest stems from the possibility of doing polarized muon-polarized target scattering and of using the muon decays in the ring as a source of electron-type neutrinos. The sequence would be to accelerate protons to 200 GeV in one ring, use them to produce pions on a target, take the pions into the other ring and hold on to the muons from their decay. It is estimated that about 3×10^9 *muons (beam intensity of about* 10^7 *per s) could be held for a mean lifetime of 2 ms. Polarized targets could be introduced into the orbiting beam. A straight section (100 m long) could be used as a neutrino source and the muon decay rate would give about* 10^8 *neutrinos (beam intensity of about* 3×10^5 *per s). The neutrino beam would have attractive properties compared to those from conventional sources.*

Uranium at Darmstadt

On 29 March uranium ions were accelerated in the heavy ion linear accelerator, UNILAC, at GSI (Gesellschaft für Schwerionenforschung) Darmstadt. The ion energy at the



output end of the machine was 5.9 MeV per nucleon. On 1 April four additional single gap cavities were in action and the output energy was increased to 6.6 MeV per nucleon. Injection into UNILAC was with uranium ions of charge 10. They were further stripped to charge 41 in a carbon foil at an energy of 1.4 MeV per nucleon. Accelerated uranium ions has been one of the main ambitions at Darmstadt.

The full size prototype of a quadrupole for the 200 GeV storage ring project, ISABELLE, at Brookhaven. The magnet has operated successfully.

(Photo Brookhaven)

ISABELLE quadrupole successfully tested

A full size prototype of the quadrupoles for the 200 GeV proton storage rings project, ISABELLE, has been tested recently. It achieved a gradient equal to the design value of 0.5 T/cm on the first energizing. After a few quenches, a gradient of 0.65 T/cm was achieved at 4.2 kA. The magnet is 1.5 m long and has an aperture of 12 cm. The method of construction is identical to that used for the dipole magnets and the coils were formed in the same molding fixture. A braided conductor identical to that of the dipole was used to wind the coils. Detailed measurements of the magnetic field distribution are now being made. The quadrupole will then be used in the 'ISABELLE Cell' which is currently under construction.

Fred Mills to CTR

Dr. Frederick Mills has been appointed Associate Director of the CTR program at Argonne. Fred Mills is among the best known of accelerator physicists since his years with MURA 1956-1967. He has since been at Brookhaven as Chairman of the Accelerator Department (1970-1973) and, more recently, at Fermilab.

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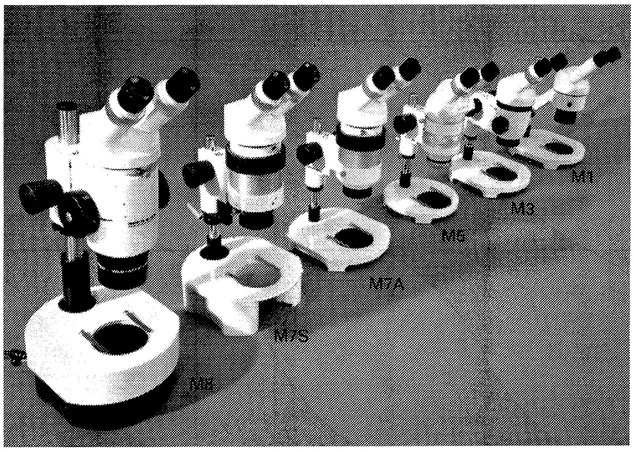

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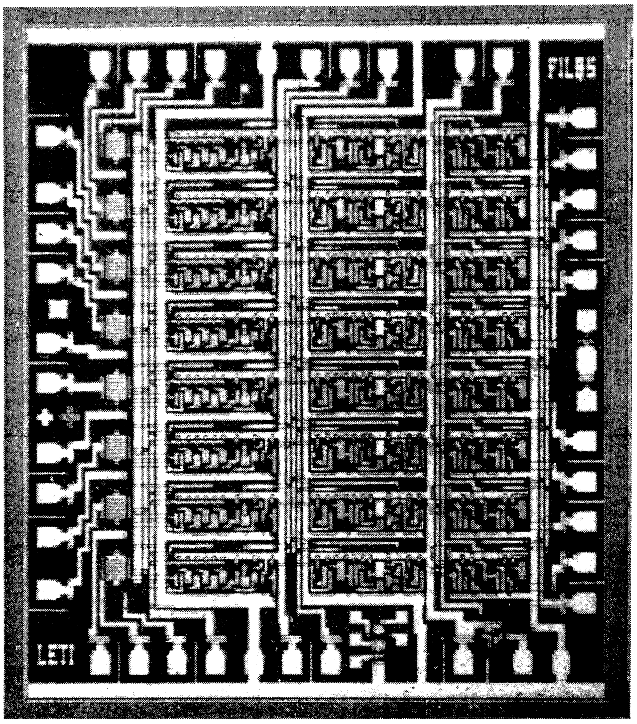
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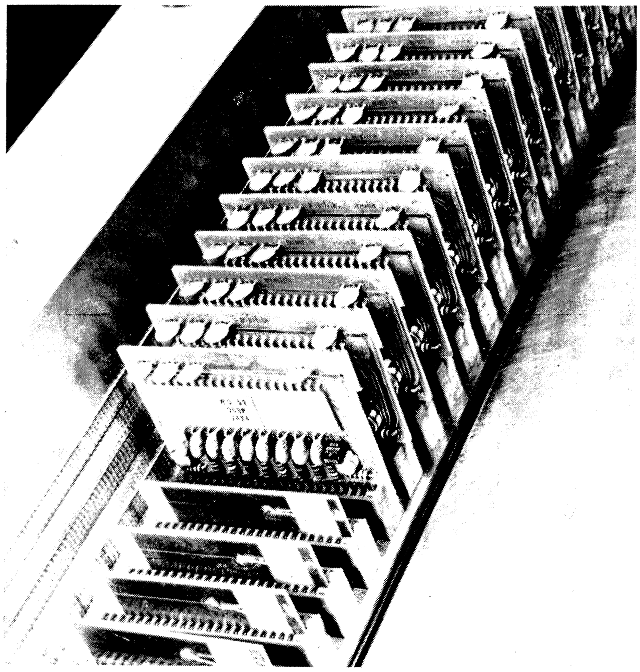

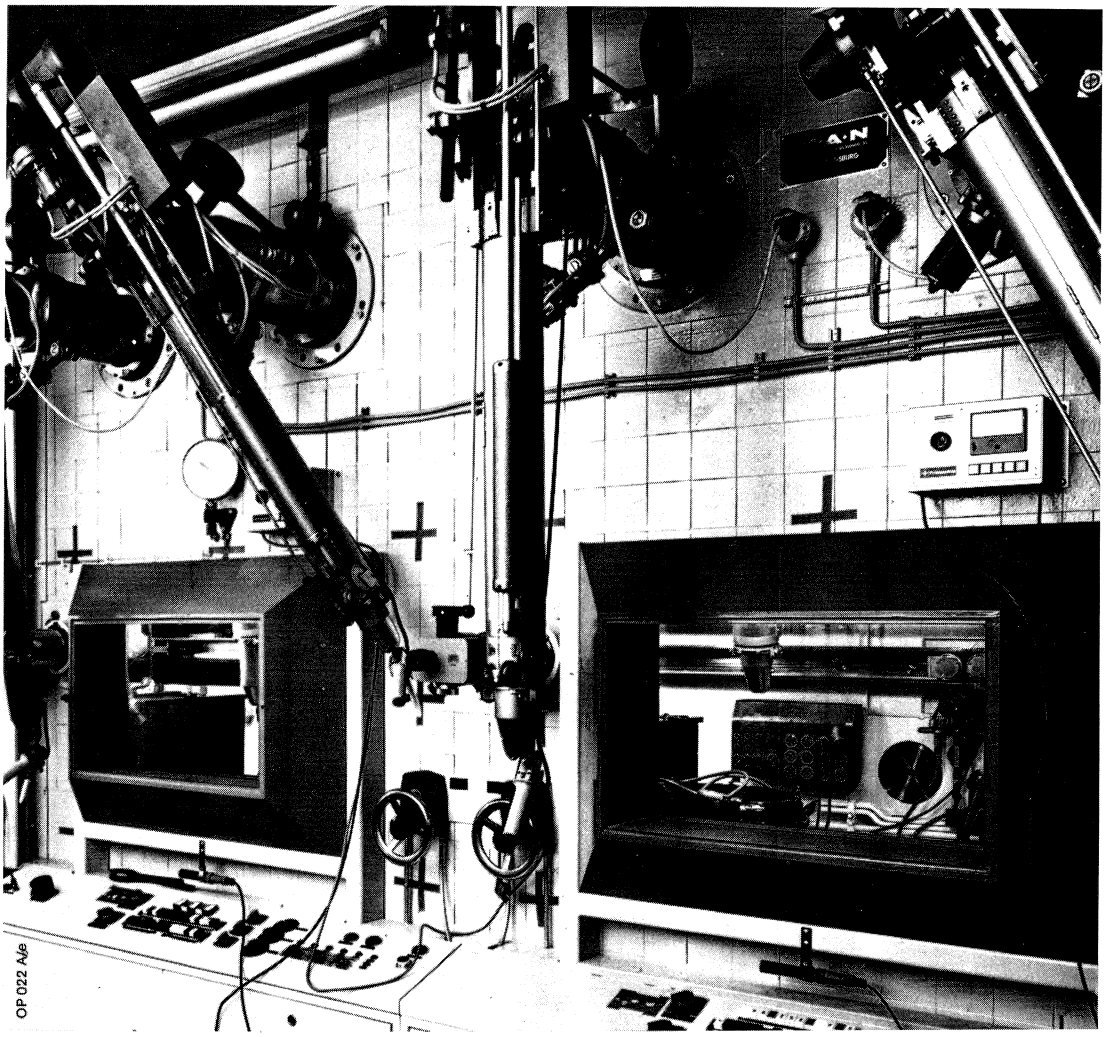
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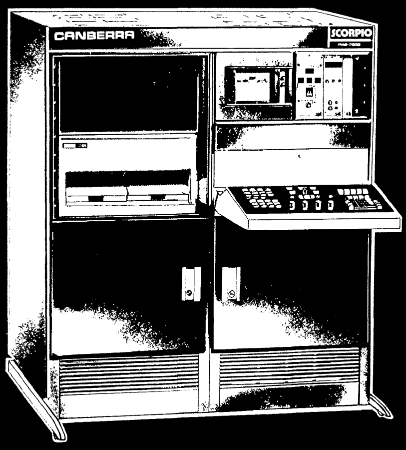

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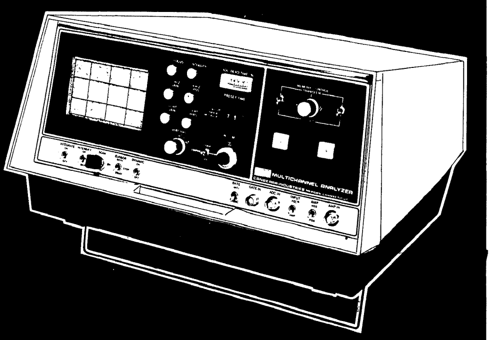

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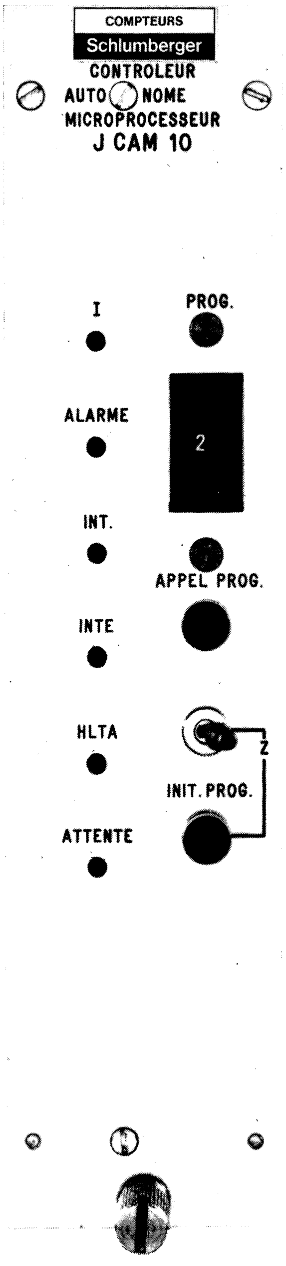

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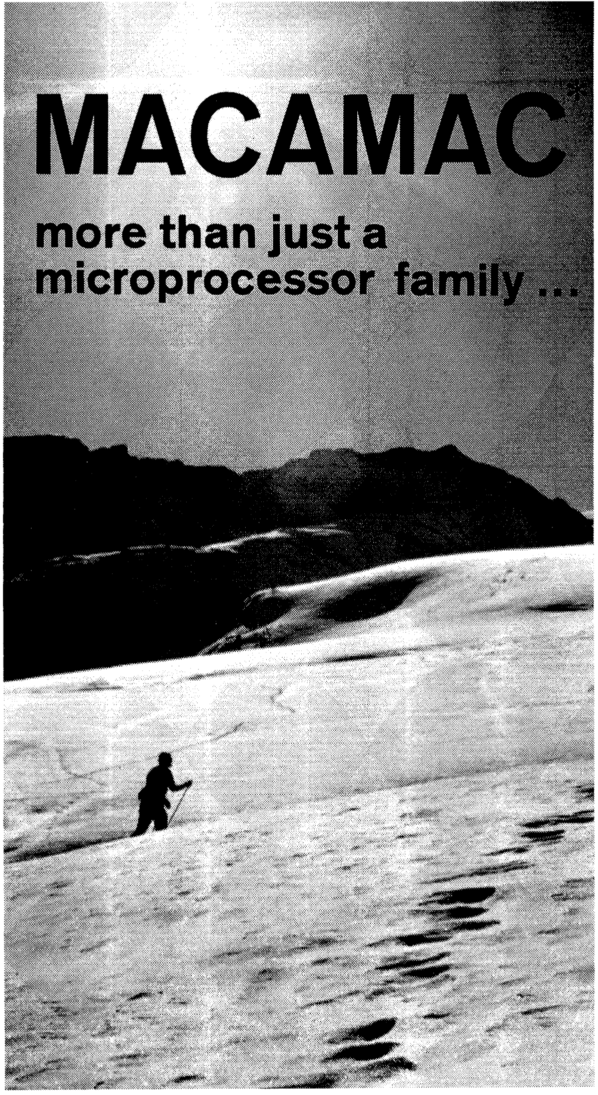

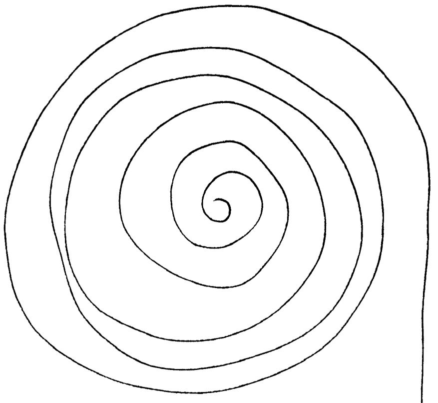

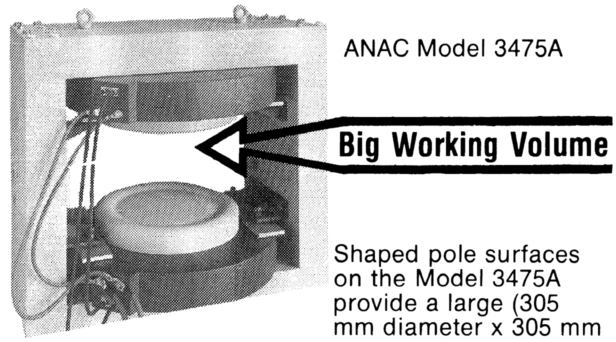
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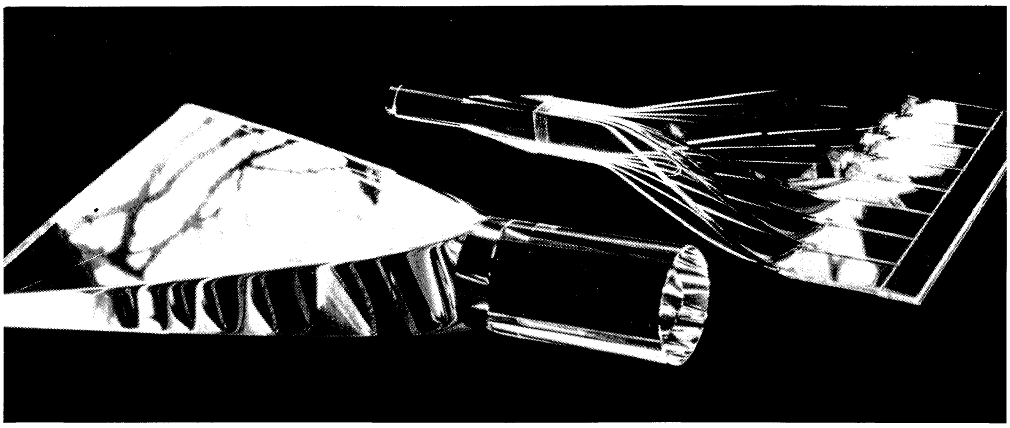
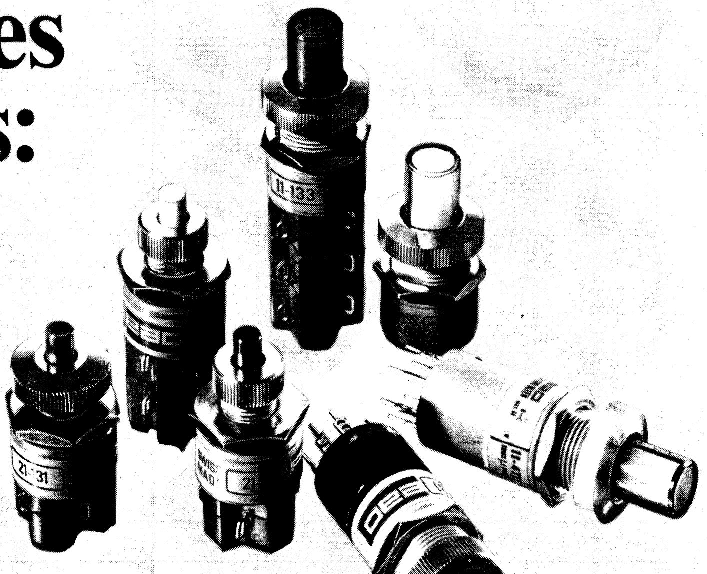
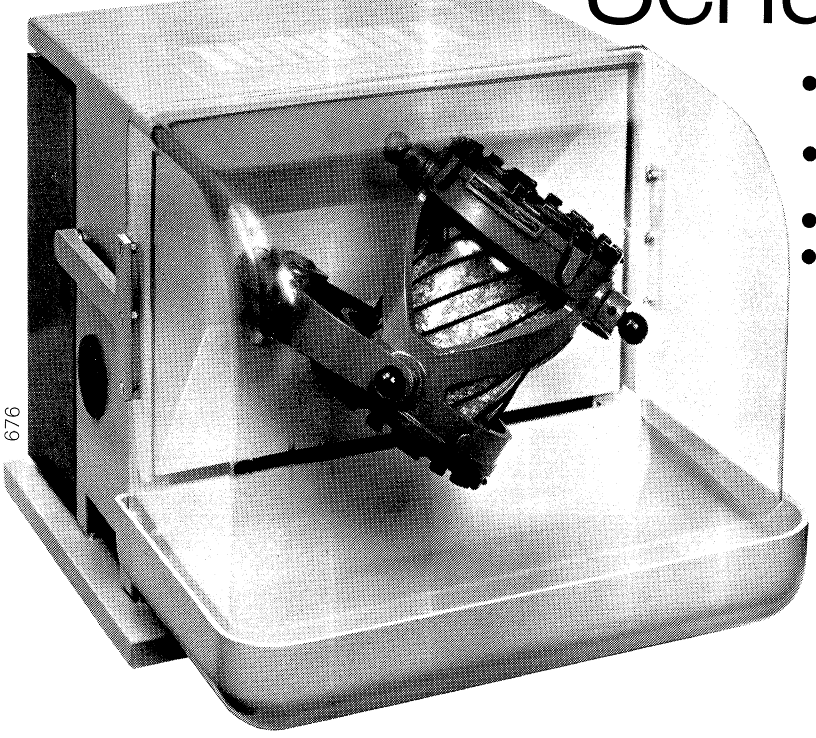
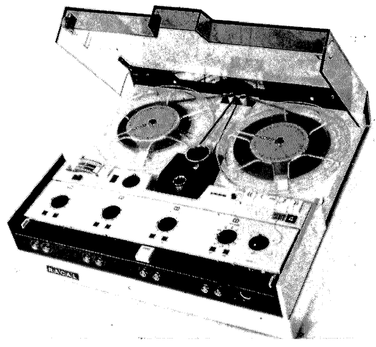
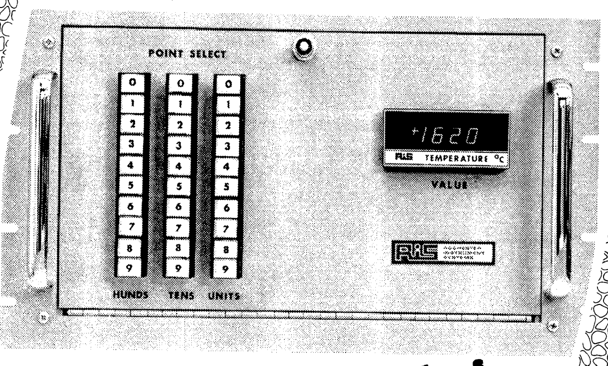



11-133
21-31



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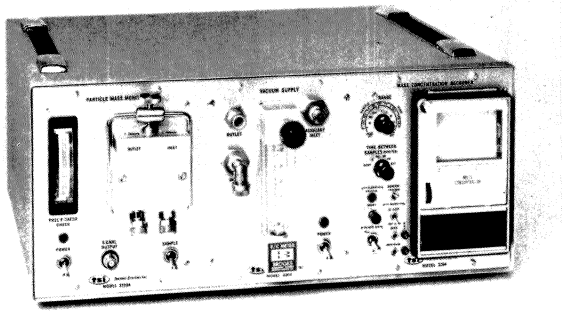

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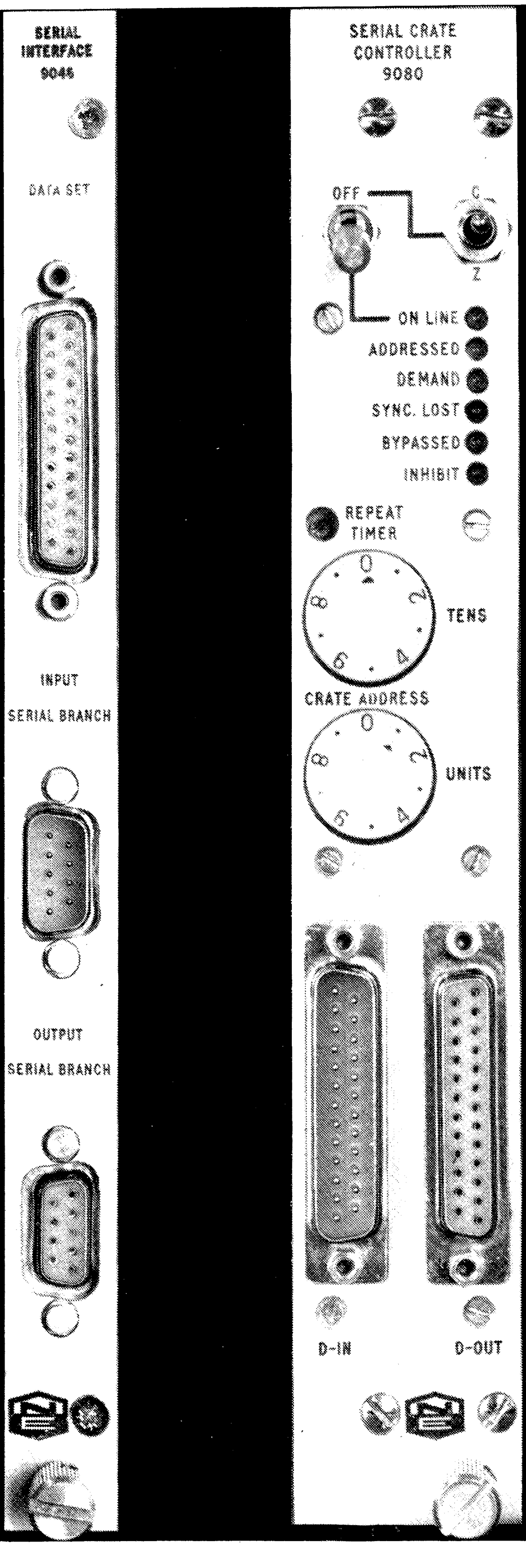
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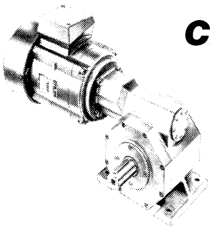
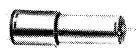
Cherchez-vous des motoréducteurs de haute précision, silencieux, avec une longue durée de vie?

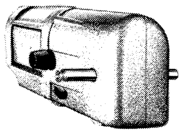


Choisissez du programme

ZÜRRER les motoréducteurs à vis sans fin jusqu'à 1300 Nm



dunkermotoren les plus petits jusqu'à 1000 Ncm



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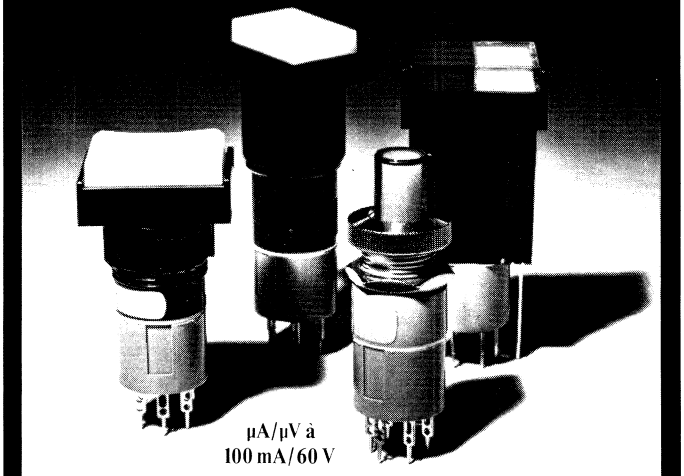
Commutation sûre des faibles puissances:



µA/µV à
100 mA/60 V

low level

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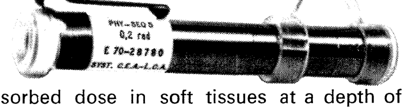
PEN DOSIMETERS

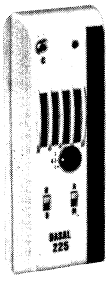
SEQ 5



Measures the absorbed dose in soft tissues at a depth of 300 mg/cm², due to photons of 50 keV or above and electrons of any enegy.

SEQ 6 Measures the absorbed dose in soft tissues at a depth of 300 mg/cm², due to photons of 10 keV or above and electrons of any energy.

SEQ 7 7 mg/cm² (skin dose).



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