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Cover photograph: How to brighten up your Laboratory. A corner  
of this year's exhibition of work by the children of the CERN  
Nursery School (Photo CERN X571.5.85).

# Vancouver Accelerator Conference

*Michael Craddock, Chairman of the Conference, and Accelerator Research Division Head at the TRIUMF Laboratory gives the opening address at the 1985 Particle Accelerator Conference in Vancouver. He and his colleagues are to be congratulated on the very smooth organization of such a large gathering.*

Anyone who contends that particle physics is conducted in an ivory tower, not contributing to other fields of science or to humanity at large, should have attended the 1985 Particle Accelerator Conference in Vancouver. Over a thousand participants contributed 781 papers and only a fraction were actually related to accelerators for high energy physics. The majority of present developments are in the service of other fields of science, for alternative power sources, for medicine, for industrial applications, etc.

Nevertheless, it is the spur of high energy physics that has driven accelerator technology along. As Burt Richter pointed out, in some fifty years since the first Cockcroft-Walton accelerators were built, accelerator physicists have increased peak machine energies by a factor of a million and have reduced the cost per GeV by a factor of over ten thousand. Conference Chairman Mike Craddock rejoiced in his opening address that the contributions of the accelerator community had been so significantly recognized at the end of the last year with the award of the Nobel Prize to accelerator physicist Simon van der Meer, jointly with Carlo Rubbia, for his part in the success of the CERN proton-antiproton Collider.

## *The big machines*

Maury Tigner, Head of the Central Design Group based at Berkeley, gave an overview of progress towards the US 20 TeV Superconducting Super Collider, SSC. Their next major decision is the selection of the type of magnet, which of course carries a host of other parameters in its wake – particu-

larly the machine diameter.

Though there are variants – such as two-in-one (both beam apertures in a single yoke) or one-in-one designs – there are essentially two basic magnet types now under consideration. The superferric, low field type aims for simplicity and attendant low cost. Work on their design (reported by Russ Huson) is at the Texas Accelerator Centre where most impressive progress has been made for such a newly created team. They have built and tested a series of 1 m and 7 m magnets, concentrating mostly on a two-in-one design, and are now assembling a 28 m prototype (their aim is magnet units 140 m long, including dipoles 105 m long, of which there would be 1330 around the ring). Magnet performance has been good with no training, no quench-

ing problems, good cooling and with straightforward manufacturing processes.

Paul Reardon reported on the alternative high field type for which the initially separate proposals of Fermilab and of Brookhaven/Berkeley have now been amalgamated in what is called 'Design D'. They have built 4.5 m prototypes, 4 cm aperture, plus other prototypes for specific purposes, and have been encouraged by the recent improvements in superconductor cable quality (mentioned also in the recent story on HERA at DESY, see June issue, page 179) giving 25 kA/mm<sup>2</sup> rather than the 18 kA/mm<sup>2</sup> of the cable used for the Fermilab Tevatron, which makes higher fields accessible. Six 17 m magnets are now under construction; they are one-in-one, 4 cm bore, cold iron.



*The 1985 Particle Accelerator Conference gets underway. The Conference, the eleventh in the series (based in the USA prior to this excursion over the northern border), was held from 13 to 16 May, attracting over a thousand participants.*

A look at operational considerations (Peter Liman) does not give a clear message on low field versus high field magnets for the SSC. The low field, larger ring would be some 5 to 10 per cent more expensive to operate. The high field is more susceptible to trouble from collective effects and from synchrotron radiation (new to proton machines) in cryogenic conditions. Some experiments are planned on the Brookhaven 'Light Source' to give better estimates of the potential radiation problems. To retain its key attraction, however, the low field type will have to retain comparative simplicity of construction. As designs advance, it is not obvious that this will definitely be the case.

Site selection for the SSC is the most 'political' of the project decisions, apart of course from the overall project authorization. Jim Sanford described the present thinking on site layout. A 'composite' site has been invented in order to spell out the needs and get a feeling for costs. The Department of Energy has set up a selection procedure (involving outside experts) and the hope is that the decision would be taken at the end of 1986. If everything goes according to schedule, and authorization for the project is forthcoming, construction could begin in 1988.

Of the big machines already under construction, we have reported recently on LEP (May issue, page 132), covered at the Conference by Herwig Schopper, and HERA (June issue, page 179), covered by Bjorn Wiik. The Stanford Linear Collider, to achieve 50 GeV electron-positron collisions and to prepare the way for very high energy lepton colliders, was covered by S. Eckland. All the tunnelling for the two



arcs, which will lead beams from the upgraded SLAC linac into collision, is complete and some 900 bending magnets for the arcs are available. The aim is to start commissioning of the arcs in the autumn of 1986. On the linac itself, the electron gun is giving over  $5 \times 10^{10}$  per bunch, the tiny damping ring has stored  $4 \times 10^{10}$  electrons, new focusing and guidance systems are being installed and the klystron and SLED upgrade of the linac is meeting specification.

The TRISTAN 30 GeV electron-positron collider project at the Japanese KEK Laboratory was mentioned in an overview of accelerator projects in Japan by Y. Hiras. The 2.5 GeV injector is operating and the accumulation ring is now being commissioned.

News from the big machines presently in operation concerned

the CERN proton-antiproton Collider (Bas de Raad and Robin Lauckner) and the Fermilab Tevatron (G Dugan). The Collider performance climbed to an integrated luminosity of almost  $400 \text{ nb}^{-1}$  in 1984 (see page 229) and the current programme of improvements – particularly the construction of ACOL to give an order of magnitude improvement in the number of antiprotons stored per day ( $10^{12}$  rather than  $10^{11}$ ) and a change to six bunch operation – should take the luminosity to about  $4.4 \times 10^{30}$  per  $\text{cm}^2$  per s with coasting beams at 315 GeV. The recent pulsed operation of the Collider sacrificed luminosity to take a look at higher collision energies (up to 450 GeV) and, in a very successful machine run, provided 95 hours of physics.

Commissioning of the antiproton source at the Tevatron started

on 10 May. The antiproton yield with the lithium lens in operation has been measured as  $3 \times 10^{-5}$  per proton. Previously the debuncher ring was checked out with 8 GeV protons and beam was stored for the first time in April; now it is the turn of the accumulator ring where the stochastic cooling systems are installed. The superconducting ring has been tested as a storage ring with protons and has held beam for four hours. The hope is that antiprotons will be transferred to the Tevatron in July and that the first proton-antiproton collisions will be observed in August. Operation is likely to be at energies up to 800 GeV per beam, pushing to 1000 GeV later.

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#### *Accelerator technologies for the future*

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While the above paragraphs communicate that the accelerator community has much to keep it busy in the cause of particle physics for some years to come, there is also the realization that with LEP and SSC we are bumping into physical and fiscal limits in the climb to the ever higher energies demanded by the particle physicists. Thus, despite the burden of present projects, some hardy souls have started the very long term search for new methods of acceleration which would bring down the size and cost of the next century's machines.

The technologies need to be radically different. Recent advances, like the hard won mastery of superconducting magnets and radiofrequency cavities, do not take us far enough beyond previous techniques. We have de-

scribed some of the new ideas before (see, for example, December issue 1984, page 436), and several schemes remain in favour – particularly laser beat waves, wake field and two-beam schemes.

C. Joshi reviewed those involving access to the high accelerating field of laser beams (1 TV/m transverse). A number of exploratory experiments are underway or proposed at the UK Rutherford Laboratory, in Canada, and at UCLA and Los Alamos in the US. At UCLA a CO<sub>2</sub> laser experiment has achieved accelerating fields of up to 1 GV/m via beat waves in plasmas. Over the next few years it is hoped to demonstrate acceleration of electron beams with such beat waves. Joshi emphasized that this research with lasers will be fruitful in any case since the special characteristics of the laser fields will be applicable in other areas such as the focusing of beams, ion guns and power sources.

Tom Weiland described work on the wake field scheme at DESY. The immediate aim is to demonstrate that short pulses of high gradient fields (over 100 MeV/m) can be achieved in structures where the wake fields left by hollow beams in an outer channel are transformed through to a central beam aperture. A test unit to produce doughnut-shaped electron beams has had encouraging initial tests and it is hoped to have tried the wake field transformer principle by the end of the year.

Work based at Berkeley on the two-beam scheme was reported by Don Hopkins. They are benefiting from the availability of the free electron laser facility at Livermore where the first ever operation of a FEL as a high gain

microwave amplifier was achieved at the end of last year. The idea is to use a low energy, high current (few MeV, 1 kA) beam through a wiggler to produce copious microwave radiation (35 GHz) via the FEL mechanism. This radiation then passes energy to a second beam by activating a high gradient structure. Such a structure has been made for the experiment (requiring Swiss watch dexterity in manufacture and assembly) and tests should be underway at Livermore soon. If all goes well, there are dreams of a 30 m prototype by the end of the decade.

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#### *Applications of accelerators in other areas of science*

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If the above paragraphs are already a cursory summary of the flood of information communicated at the Conference, we now move to topics where the volume of presented papers was even greater. We, therefore, take a selective look at accelerator developments in branches of science other than particle physics concentrating on synchrotron radiation sources, neutron sources, heavy ion accelerators and kaon facilities.

The explosion in the use of synchrotron radiation from electron-positron storage rings, plus wiggler and undulator additions to extend the range of the light beam characteristics, was evident in the talks of Mark Barton, Lee Teng and Michael Knotek. Barton listed 23 operating facilities (18 of them dedicated light sources) in Europe, Japan, USA and USSR. Teng added about 20 others now under construction or proposed and it was pleasing to note that some of these are in countries outside the



*The main social event took the participants out to TRIUMF on the campus of the University of British Columbia where they could tour the Laboratory and enjoy a salmon barbecue, Indian style. The weatherman decreed that this should be the one rainy day of an otherwise sunny week, which drove the barbecue indoors. Even with this complication, the excellent organization ensured a very pleasant evening.*

above usual geographic locations – Brazil, China, India and Taiwan. To give an idea of just how heavy the demand is for the use of each of these light sources, the National Synchrotron Light Source at Brookhaven operates eighteen beamlines with seventeen more planned on the X-ray ring and thirteen beamlines with eleven planned on the ultra-violet ring.

The most advanced machines are 6 GeV, very high brightness proposals in the USA (designs from Argonne, Brookhaven and Stanford) to use full energy injection into the light source storage ring after a booster synchrotron, with many long straight sections for wigglers and undulators. Such a facility was recommended by the 'Seitz-Eastman Committee on Major Facilities for Materials Research', and preparatory Workshops have been held at Ames and the National Bureau of Standards. Almost equivalent thinking is behind the design proposed for a European Synchrotron Radiation Facility (reported in a poster session by S. Tazzari). The European design has electron energy of 5 GeV with thirty straight sections (we will have an article on the ESRF in the near future). Knotek commented that the availability of such machines will bring a revolution in X-ray science equivalent to that experienced when moving from the old X-ray sources to the first light beams from electron synchrotrons.

In addition to the great impact on all areas of materials research at the present light sources, research workers in other disciplines, such as biology (where the speed at which information can be gathered allows complex structures, like proteins, viruses, and



dynamic systems to be studied), medicine (just one potential application in preventive medicine is picked out below), industrial uses (crystal studies for the semiconductor industry, lithography, microscopy, etc.) are also benefitting from access to synchrotron radiation facilities.

David Gray reported on initial operation of the Spallation Neutron Source at the Rutherford Appleton Laboratory which is taking over from the neutron sources at Argonne, Los Alamos and KEK as the most prolific source of neutrons for research. Proton accelerators bombarding uranium targets surrounded by moderators are capable of neutron fluxes far higher than those of high flux beam reactors. The research programme at Rutherford started in June, continuing to the end of the year with

proton beam energies up to 550 MeV rather than the design 800 MeV (while awaiting installation of the last two of the six r.f. accelerating cavities). There is no development on the authorization of the spallation neutron source, SNQ, proposed at Jülich in Germany.

The acceleration of heavy ions is back in the news and Nick Samios spelled out some of the reasons why. The most intriguing for particle physics is that colliding high energy heavy ions could allow access to short distances between components in the nucleons where the force acting between quarks is weak (the quark-quark binding force increases with distance). Thus heavy ion collisions could open up for study a new state of matter – the quark/gluon plasma. Energies of some 100 GeV per nucleon are probably neces-

Lee Teng, seen here touring the TRIUMF installations with his wife, gave a Conference report on the booming area of synchrotron radiation applications.



sary but the colliding ion beam luminosities need not be very high ( $10^{26}$  per  $\text{cm}^2$  per s or less).

A. Ruggiero reviewed schemes to reach such machine performance. The Bevalac at Berkeley has been the front runner in heavy ion energies for many years reaching the range of 1 GeV per nucleon for fixed target physics. They have had the ambitious VENUS project on the table since 1979 (see December 1979 issue, page 406) to reach energies of 20 GeV per nucleon in colliding beams and, in the absence of authorization, have a more modest version (the 'Mini Collider') for colliding beams at 4 GeV per nucleon in rings with 4 T superconducting magnets. Oak Ridge have a proposal for a 10 GeV per nucleon collider using ions from their operating tandem into two synchrotron/storage rings

with superferric magnets.

Brookhaven are working hard on a 100 GeV per nucleon collider known as the Relativistic Heavy Ion Collider, RHIC. Beams from the existing tandem will be transferred to the Alternating Gradient Synchrotron (the transfer line is being built and the AGS r.f. system is being modified to accept ions). Eventually a booster synchrotron would be added to allow injection of fully stripped ions. From the AGS, accelerated ions would be fed to storage rings installed in the completed tunnel which was for the CBA/ISABELLE project. (Since, for some purposes, heavy ions could extend down to protons, it has to be acknowledged that RHIC is a most imaginative way of building the CBA!) A proposal has been put forward and construction could take off in 1988 after further

R and D. The size of the user community interested in such heavy ion experiments in the USA is estimated at up to 400 scientists.

In the meantime, there are some interesting intermediate developments in Europe. At CERN, oxygen 16 ions will be accelerated through the PS and SPS and the possibility of antiproton-ion collisions has not escaped attention. For a broader programme, D. Bohme reported that authorization has recently been given for the construction of a synchrotron, SIS, to be fed by the existing UNILAC linear ion accelerator at GSI Darmstadt (see June issue, page 181). UNILAC provides ions at some 20 MeV per nucleon; SIS will take energies to 1 GeV per nucleon for uranium ions. It will be linked to an Experimental Storage Ring, ESR, which is being designed. Construction time is some four to five years (dominated by the building construction).

Kaon factory proposals were reviewed by H.A. Thiessen. The aim is to build a high intensity proton machine in the 30 to 50 GeV range to produce (amongst other beam species) a flux of kaons some hundred times higher than those available from the CERN PS and Brookhaven AGS for research in nuclear and particle physics. The Los Alamos, TRIUMF, SIN, Brookhaven and KEK Laboratories have all looked at the possibilities; the first two have developed proposals. Project preparation is most advanced at Los Alamos where the LAMPF linear accelerator would be used as injector into a booster and fast cycling synchrotron. At TRIUMF the injector would be the existing cyclotron into booster, synchrotron and storage rings. TRIUMF have obvious interest in opening up a new programme;

the existing cyclotron has been in action for a decade (in fact there will be a celebration of 'Ten Years of Scientific Research at TRIUMF on 7, 8 July). Certainly, if they build kaon factories as well as they organize Conferences they would do an impressive job!

It was intriguing that heavy ion machines and kaon factories got so much attention at the Conference – they were second and third priorities, respectively, in the recommendations for the Nuclear Physics Advisory Committee concerning the facilities most appropriate for nuclear physics research in the coming years. The first priority machine, a recirculating linac to give 4 GeV electron beams, did not figure at the Conference though preparatory work is underway at the Virginia site of the Southern Universities Research Association, SURA, under the project name of CEBAF (Continuous Electron Beam Accelerator Facility).

#### *Some applications of accelerators*

To conclude, we mention a few of the Conference topics where accelerators are used or planned, not for particle physics or other areas of scientific research, but directly in 'practical' applications.

Medical applications have been a major spin-off ever since the first X-ray machines. Now accelerators are in use for isotope production, in radiography, and in particle beam therapy. For therapy, various accelerated particles are used – heavy ions (in particular at Berkeley), protons (2600 people have been treated at the Harvard cyclotron), pions (the TRIUMF Laboratory itself has a pion radiother-

apy facility) and neutrons (for example, at Fermilab – a total of over 4000 have been treated in the USA).

Because it is so elegant, we mention in addition one recent idea for a medical application which is under investigation – heart scans using synchrotron radiation (reported by H. Wiederman). What is needed is a small (1.2 to 1.5 GeV) high intensity (1 A) light source able to provide a high flux of photons of energy 33 keV. Iodine is introduced into the bloodstream and one scan of the heart (with some  $10^8$  photons per  $\text{mm}^2$ ) is done with the photon energy just below the iodine K absorption edge and a second with the energy just above. The readings of these scans are subtracted, one from another, via computer. The only thing that changed in the two readings is the photon flux absorbed by the iodine in the bloodstream. Thus, the coronary arteries appear with remarkable clarity while the rest of the anatomy 'disappears'. Such scans could readily give advance warning of potential heart troubles and the economic values of such warnings (quite apart from the humane social value) would be great. The technique is very much faster and more pleasant for patients than the presently used techniques.

It is impossible to report on an Accelerator Conference which concentrated mostly on the work of the USA community without a few words about a proposed practical application going in the opposite direction to medical applications – the Strategic Defense Initiative, SDI, beloved of the media as 'Star Wars'. One of the mechanisms to be studied under SDI for 'zapping' alien objects is the particle beam

weapon. There were a few papers at the Conference from laboratories clearly involved in such studies which mainly reported work aimed at improving the quality of low energy particle beams. There was certainly no open information which can yet move the particle beam weapon out of the category of science fiction.

The interest in particle beams to achieve commercially viable fusion reactors via the inertial confinement technique continues and there were review papers on light ion (M. Buttram) and heavy ion (Dennis Keefe) developments. The aim is to deposit several megajoules on the surface shell of a deuterium-tritium pellet in some 10 ns requiring accelerators delivering a few terawatts. (Buttram remarked that the calculations ranged 'from the optimistic to the conservative to the realistic'.) Sandia is concentrating on producing beams of 30 MV lithium ions. A 100 TW machine called PBFA-II is scheduled for operation early next year to study beam and target behaviour under single pulse conditions. They use a high power pulse compression scheme with laser triggered spark gaps.

For heavy ions, a bank of r.f. linacs cascading ions into an Alvarez linac, followed by transfer and storage rings, remains under study in Europe and Japan. The alternative scheme using induction linacs is pursued in the USA. An induction linac, MBE-4, to demonstrate current amplification with four caesium ion beams is under construction at Berkeley.

Also related to fusion reactor technology is the Fusion Material Irradiation Test (FMIT), a 35 MeV deuteron accelerator to provide intense fluxes of neutrons of fusion



# Collision course

reaction energies. These neutron beams will be used to study the behaviour of materials subjected to the bombardment they will receive in fusion reactors. Several papers reported progress on the machine development (for example, the successful operation at Los Alamos of appropriate radio-frequency quadrupoles for the FMIT injector; it is amazing how the new technology of RFQs has swept the board in accelerator injection systems in the space of a couple of years).

This report of the Vancouver Particle Accelerator Conference will give some feeling for the range and the volume of modern accelerator physics and technology.

*By Brian Southworth*

On 10 July 1981, Carlo Rubbia burst into the Lisbon Particle Physics Conference clutching the first recordings of high energy collisions of matter and antimatter in the CERN SPS ring. His announcement, the culmination of many years of intense and careful preparation, was greeted with spontaneous applause.

More than three years later, the SPS Collider's performance has improved more than a hundred-fold, but the applause has died down. With the collection of antimatter mastered and almost routine, Lyndon Evans and Vincent Hatton review the achievements to date and the lessons learned.

The Collider's peak luminosity (a measure of the instantaneous proton-antiproton collision rate) has been pushed up by almost

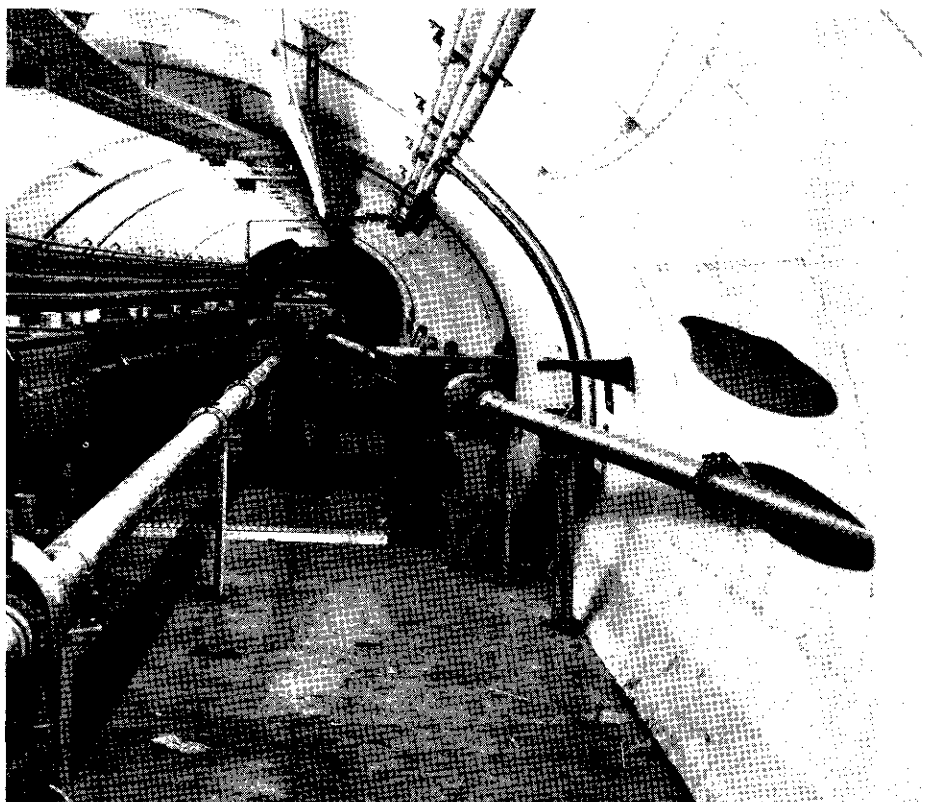
two orders of magnitude from  $5 \times 10^{27}$  per  $\text{cm}^2$  per s in 1981 to  $3.5 \times 10^{29} \text{ cm}^{-2} \text{ s}^{-1}$  in 1984. More important, the daily average performance (integrated luminosity) has increased by more than an order of magnitude.

In view of the scarcity of antiprotons, the reliability of the whole chain of injectors is of crucial importance. The SPS itself is particularly vulnerable to faults, due mainly to its large size and heavy demands on primary services.

After the first proton-antiproton collisions were recorded in the summer of 1981, the first physics run took place at the end of that year, when  $2 \times 10^{32}$  per  $\text{cm}^2$  ( $0.2 \text{ nb}^{-1}$ ) of integrated luminosity was produced. In the second run at the end of 1982 the peak luminosity was increased to  $5 \times 10^{28} \text{ cm}^{-2}$

*Emerging from the tunnel wall on the right is the beamline which feeds 26 GeV antiprotons from the PS to the CERN SPS. On the left are proton lines emerging from the SPS main ring.*

*(Photo CERN 38.4.81)*



*The control room – nerve centre of SPS operations.*

*(Photo CERN 169.6.83)*



$\text{s}^{-1}$  and a total integrated luminosity of  $28 \text{ nb}^{-1}$  was produced, enough to reveal the long-awaited W particle. In the spring of 1983 the peak luminosity was pushed up to  $1.7 \times 10^{29} \text{ cm}^{-2} \text{ s}^{-1}$  and a total of  $153 \text{ nb}^{-1}$  was produced in each of the two experiments. Finally in the latest big run (end 1984) the peak luminosity was further increased to  $3.5 \times 10^{29} \text{ cm}^{-2} \text{ s}^{-1}$  and a total of  $395 \text{ nb}^{-1}$  was produced in each experiment.

These runs used continuously stored (d.c.) beams, first at a collision energy of 540 GeV, then in 1984 at 630 GeV. This year (see May issue, page 131), a new technique was used in which the collision energy attained 900 GeV for brief periods.

The steady improvement in Collider performance reflects a gradual mastering of a complex chain

of accelerators. At least three days of stacking of antiprotons in the antiproton accumulator (AA) is required before making the first transfer to the SPS with an initial luminosity in excess of  $10^{29} \text{ cm}^{-2} \text{ s}^{-1}$ . Once the initial stack is established, equilibrium is reached where approximately 30 per cent of the stack is transferred to the SPS in three bunches. As long as the SPS can hold the beams for of the order of 20 hours, the AA then has time to replenish the stack ready for the next transfer.

The security of the transfer sequence is improved by using software. The nucleus is a high level job manager called the 'sequencer'. This controls the complex series of operations needed to prepare the SPS and its transfer lines and to control the antiproton injection process. It can abort the

transfer up to the very last moment if a fault is detected. Such elaborate software control is more reminiscent of a rocket launch than an accelerator operation.

In the first three years of operation, useful luminosity could be maintained for some 15 hours, being limited mainly by the antiproton beam lifetime. This is well suited to the cadence of one antiproton transfer per day. If the coast is terminated manually the SPS is prepared for the next injection as quickly as possible. Generally three or four hours are necessary to follow fully all the procedures, retune the machine, check the beamlines with protons, inject antiproton pilot pulses, etc. However, as will be shown later, at least one third of the coasts are terminated prematurely. In these cases it is often unattractive to

Erwin Gabathuler (CERN Research Director at the time, second from left) had promised a crate of champagne if the maximum proton-antiproton collision luminosity achieved in the SPS during the initial operations in 1981 could be increased tenfold in the 1982 run. Enjoying his generous offer with him are (left to right) André Faugier, Lyndon Evans (one of the authors of this article), Jacques Gareyte and Robin Lauckner. Luminosity has since been boosted considerably and more champagne has appeared from time to time.

(Photo CERN 209.11.82)



## Hitting a barn

*Integrated luminosity is a way of gauging the total number of collisions over a period of time. An area is imagined to surround an antiproton, say, and one asks how many times a proton went through this area. The nanobarn, the area commonly used in particle physics is tiny –  $10^{-33} \text{ cm}^2$ .*

*A 'barn' ( $10^{-24} \text{ cm}^2$ ) is the target area offered by big nuclei like uranium, and even in the old days of nuclear physics, hitting these giant nuclei was 'as easy as hitting a barn'. The name stuck.*

prepare quickly for a new fill since time is needed for the accumulator to replenish its stack.

There has also been a gradual increase in the percentage of time available for experimental physics compared to the total scheduled operating hours.

Other than providing beams for the experiments, there are four other time-consuming tasks: setting up for coasts, machine studies, access, mainly for the experiments, and fault diagnosis and equipment repair.

The efficiency of the Collider is judged by the experimental teams on the combined basis of total hours of colliding beam and luminosity. Thus the figure which really counts is the integrated luminosity. Its increase by a factor of 2.6 from 1983 to 1984 was more significant than the increase

in duty factor from 43 per cent to 50 per cent.

In the early stages of an experiment there is little demand for peak luminosity performance and it is the total number of hours with collisions which is important. This is also the case at the beginning of a new period of operation, and there are also demands for low luminosity calibration runs. The time requested for calibration and setting up runs in any year however is small, less than 10 per cent of the total scheduled time.

The average time for setting up in preparation for a fill is nearly six hours. This reflects the dependence on the number of antiprotons available in the accumulator rather than any inefficiency in the preparation. The time between fills is particularly long following the loss of a stack

due to a technical failure.

Access requests are grouped together and scheduled as much as possible in advance since full use has to be made of these relatively rare occasions. It is not unusual to have 30 people entering the UA1 zone for a four-hour access period. Shorter accesses between fills are also catered for.

Access for accelerator repairs is combined with access to experiments. Much of the power supply testing and improvement was done during access to the experimental zones.

Machine studies require a variety of beam conditions. In addition to studies on the end of a physics coast, time needs to be set aside for proton-only coasts and collisions with pilot (low intensity) antiprotons. Both these uses of scheduled time are neces-



sary for the efficient operation and development of the accelerator and the experiments and should not be considered as counterproductive.

Of the 77 coasts in the 13-week 1984 run, 25 were terminated prematurely due to technical failures. For the rest the average store duration was 17 hours. The 1984 record was 31 hours and the all-time record is 42 hours.

If a coast lasts longer than seven hours, the chances are it would be 'killed' by the crew at the end of its useful life.

The coast ceases to be useful for physics after the luminosity has fallen. The useful luminosity lifetime for most of 1983 and 1984 was less than 20 hours, typically between 13 and 15 hours. Of course any decision is dependent upon another fill being available. If there were problems with the proton/antiproton supplies, the coast was kept longer, hence the occasional exceptionally long coasts. At the end of the coast for physics, machine studies would frequently occupy another two hours.

There was a tendency to favour a 24-hour cycle of filling. Equipment that is used only during the transfer, injection and acceleration process can only be tested out of coast mode; it is more efficient to uncover problems during the normal working hours of the laboratory.

As the useful luminosity lifetime increased from 20 to about 26 hours and equipment reliability improved, the 24-hour cycle was abandoned in favour of increased coast time and higher integrated luminosity.

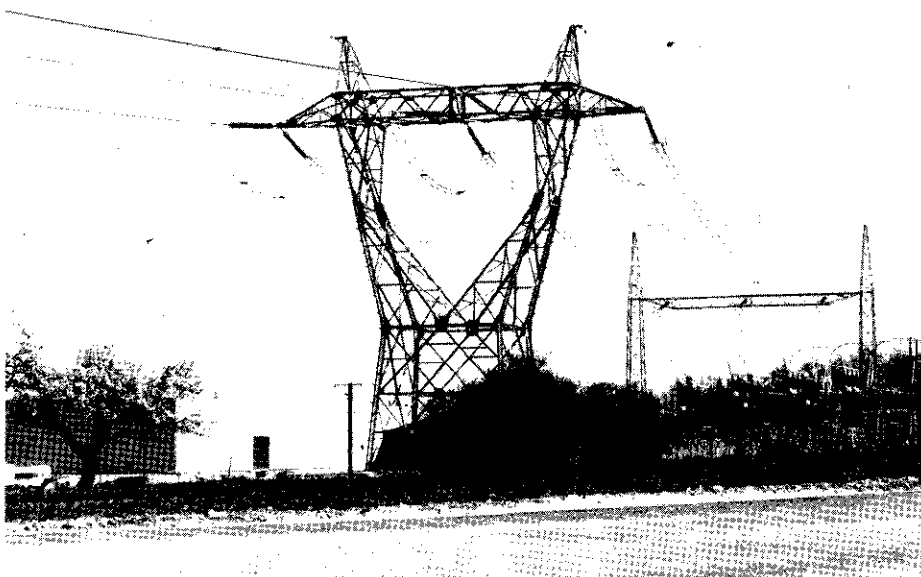
In 1983 and 1984, the majority of technical faults were caused by

random failures, mostly minor and unrelated. During fixed target operation (53 per cent of total scheduled time per year for physics) faults are analysed and repaired with the more stringent collider operation in mind.

Voltage dips on the mains supply (on an overhead line directly from a hydroelectric source at Genissiat, 50 km from CERN) contributed about 30 per cent of the technical failures in 1982 and 1983. In the latter part of the 1983 run and for the 1984 period, the system was desensitized to stand dips of up to 25 per cent on any of the three phases before the power supplies tripped. The SPS Collider never operates during the summer months. Evening thunderstorms are common in July and August and have caused serious perturbations even for fixed

*The most important single external perturbation at the SPS is voltage fluctuation on the main 380 kV overhead feeder lines, which are especially vulnerable during summer thunderstorms.*

*(Photo CERN 126.5.75)*



target operation.

For the increase from 273 to 315 GeV coasting energy in 1984, one modification was the installation of booster water pumps in all sextants of the ring. The upgrade was very successful, but two coasts were lost. Diagnosis and effective elimination of the fault can be hampered by human errors owing to the lack of familiarity with such new conditions. Striking a balance between reliable operation and the need to improve running conditions is a constant dilemma.

Care must be taken that all magnets acting on the primary beams are engineered to the same high standard as the accelerator components. Some coasts have been lost because detector magnets have failed to respond correctly (the necessary balance

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between the magnet and its compensator magnets has sometimes not been observed).

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### *Beam quality*

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The SPS Collider's operation is restricted by the availability of antiprotons. The required degree of reliability of its equipment must be higher and loss of stored beam is more serious than in the case of a proton-proton collider.

But all colliding beam machines have to provide stable conditions with low backgrounds over long periods of time. This is beam quality.

Good operation needs good diagnostics. In the case of the Collider, the measurements of beam parameters and confidence in the results is of paramount importance. In fact the performance improvement has been closely correlated with the development of improved diagnostics. Uncertainty caused by a doubtful measurement can hinder an investigation, preventing a logical diagnosis. Without reliable measurements, problems of high background, for example, cannot be traced to a movement in the closed orbit due to magnet drifts or distinguished from a problem with the beam scraping system.

One high background problem was finally traced to a noisy linear potentiometer which controlled the position of a collimator block; once identified the problem was quickly solved, but many hours were spent following false trails.

Important in the search for improved beam quality is for the control system to accommodate flexible operation. New ideas and newly identified sources of diffi-

culty must be included in the software so that the human element can be minimized. Once an operational procedure is established it should never be overlooked and this logically means converting it into software.

For good beam quality and diagnostics it is important to have good databanks not only of the equipment parameters but also of the beam characteristics. Being able to study the evolution of a parameter over a number of shots is very important and encourages lateral thinking.

As in any other storage ring the operation of the SPS as a proton-antiproton collider imposes severe demands on equipment reliability. The scarcity of antiprotons in particular excludes fast refilling after equipment failure and makes the impact of such faults on the overall productivity particularly dramatic.

The Collider is particularly vulnerable to fluctuations in the primary services. The most important single perturbation outside the control of the SPS team is voltage fluctuation on the main 380 kV supply. This problem is accentuated by the long exposed overhead feeder lines to CERN, and excludes colliding beam operation in periods of thunderstorm activity (most of the summer).

The average time of 5.9 hours needed to refill the machine is mainly determined by the number of antiprotons available in the accumulator. Nevertheless, the achievement of the best possible beam quality, transfer efficiency, emittance, etc. requires a very careful, systematic setting-up for each fill, needing at least two or three hours.

While the performance improvements achieved so far at the SPS Collider are impressive, the ingenuity and resourcefulness of the operating teams is far from exhausted. We can hope to see many more antiproton milestones in the years to come.

# A quarter of a century against the clock

*25th anniversary time. Derek Lowenstein (left), chairman of Brookhaven's Alternating Gradient Synchrotron (AGS) Department, presents a backwards-running clock to Ernest Courant, one of the pioneers of the AGS, which produced its first counter-clockwise protons 25 years ago.*

Twenty-five years ago, on 17 May 1960, the gleaming new Alternating Gradient Synchrotron (AGS) at the Brookhaven National Laboratory, New York, got its first taste of protons. But it took a few more months to prepare the radiofrequency system which transformed the new ring from a toy into the most powerful particle accelerator in the world. On 29 July 1960, protons were whipped through the dreaded phase transition and accelerated to the 30 GeV design energy. The AGS had wrested the high energy crown from CERN's new Proton Synchrotron, which had achieved 24 GeV just five months previously.

The AGS was the first proton accelerator project to incorporate from the start the revolutionary idea of strong focusing. In 1952, Brookhaven's Cosmotron, an old-style weak focusing machine, had supplied its first 3 GeV protons – the first time the 1 GeV barrier had been breached. The same year, a group of European machine specialists (Edouard Regenstein, Frank Goward, Odd Dahl and Rolf Wideroe) from the infant CERN came out to see what was happening. They were toying with the idea of building a scaled-up version of the Cosmotron as the first big machine for their new Laboratory.

Cyclotron pioneer Stan Livingston organized a study group to consider what advice Brookhaven could give the Europeans. During the deliberations, Livingston had a brainwave. The Cosmotron magnets all faced outwards, making it easy to extract negatively charged particles from a target in the machine, but not positive ones. Livingston's idea was to have some magnets facing in-



ward, some outward.

The initial idea was just to get easier access to positive beams, but soon bigger payoffs became evident. Collaborator Ernest Courant found that rather than damaging the proton orbits, the new idea seemed to improve the focusing. Hartland Snyder recognized an analogy with optics, where alternate focusing and defocusing lenses of equal strengths are focusing, no matter which comes first. With the stronger focusing, magnet apertures could be cut from the 8 × 24 inches of the Cosmotron down to matchbox size.

(Unknown to the Brookhaven team, this idea had already been developed by a Greek lift engineer called Nick Christofilos whose hobby was particle accelerators and who read the Physical Review

in the American Library in Athens. On a trip to the US in 1952, he saw the classic strong focusing paper by Courant, Livingston and Snyder, and went along to Brookhaven to tell them he had done it all before. John Blewett (also part of Livingston's study group) writes 'at first we thought he was a phony but gradually facts emerged to support his claim. We changed our minds and offered him a job, which he accepted.'

The CERN team, which had unwittingly breathed hard enough down Brookhaven's neck to make Livingston and Co. come out with something special, hurriedly changed the design of their new machine in midstream. At Brookhaven, Leland Haworth persuaded the US Atomic Energy Commission, very concerned with secret work in those days, to let Brook-



haven publish the new ideas, and a modest six-page letter proposed the building of the machine which was to become the AGS. (At Cornell, the strong focusing technique was immediately incorporated into a new electron synchrotron which began operations in 1954.) The CERN team, under the direction of the late John Adams, went on to get their proton act together faster than Brookhaven.

After the suspense of the construction race, the AGS and the CERN PS machine embarked on their separate careers. There the story was different. At the AGS in 1962, a team led by Mel Schwartz, Leon Lederman and Jack Steinberger discovered that there were two types of neutrino. In 1963, James Cronin and Val Fitch made the AGS beams reveal the mys-

tery of CP-violation – the cunning way the neutral kaons break the rules of conventional physics. In the same year, an AGS experiment led by Nick Samios spotted the omega-minus particle, and a new way of looking at physics suddenly clicked into place.

Thanks to these and other discoveries in the 1960s, Brookhaven took over from Berkeley as the world's premier particle physics Laboratory. As if to confirm that the initial bumper crop of results was no flash in the pan, a 1974 experiment led by Sam Ting at a more mature AGS discovered the

*Pioneers of the AGS Brookhaven Alternating Gradient Synchrotron alongside an early scale model which showed the great reduction in AGS magnet aperture compared to that of the Brookhaven Cosmotron thanks to the invention of the alternating gradient focusing system. From left to right are a youthful Ernest Courant, Stanley Livingston, Hartland Snyder and John Blewett.*

J/psi particle and opened the door to charm and more new physics. (The J/psi was simultaneously discovered by Burt Richter at Stanford.)

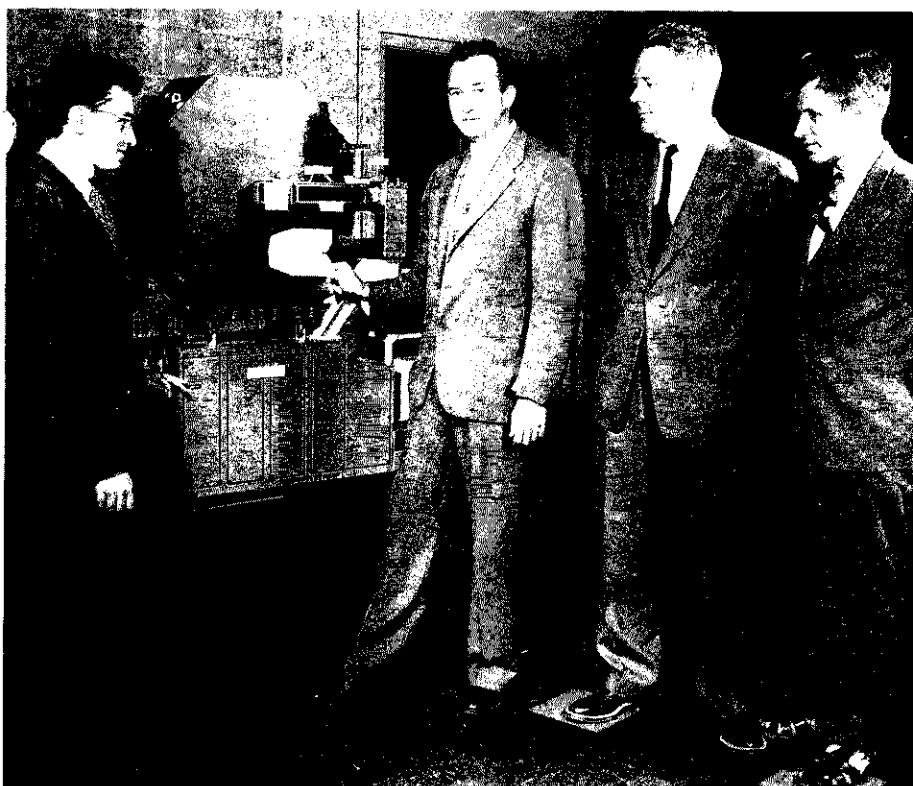
Against this impressive list of achievements, the CERN PS had only one of similar stature – the sighting in 1973 of the neutral current of the weak interaction. But by then the PS had embarked on a new career, supplying protons to the big SPS machine built alongside.

Towards the end of the 1970s, ambitious plans were again being formulated at Brookhaven and CERN. At Brookhaven, the AGS would feed the big ISABELLE proton-proton collider. At CERN, the SPS was already operating with particles from the PS. The plan was to adapt the SPS to work as a proton-antiproton collider as well as a proton accelerator. While ISABELLE foundered, the CERN project went from success to success, achieving in its first years of operation the heady achievements which had been the privilege of the AGS physicists in the early sixties.

However the spirit of the AGS physics teams remains indomitable. After 25 years, the machine's physics potential is far from exhausted, and a whole list of improvements is being pushed (see next story).

## Plans for the future

Brookhaven is committed to the continuation of its robust high energy physics programme and to the initiation of a comprehensive fixed target and colliding beam programme for high energy (relativistic) heavy ions. These initia-



tives result from the work of the AGS II Task Force (see June 1984 issue, page 194) and other committees.

The immediate particle physics plans centre on improvements to the 25-year old AGS – raising proton beam intensities up to  $5 \times 10^{13}$  particles per pulse, reliabilities from 75 to 95 per cent, and beam duty factors from 25 to 45 per cent; building a new booster injector; improving beamlines and detectors, and capitalizing on the spin physics capabilities which opened last year (see October 1984 issue, page 328).

After this, a stretcher ring is envisaged to increase duty factors to 90 per cent or more, and power supply and radiofrequency improvements to push intensities up towards  $10^{14}$  protons per pulse, together with further beamline

and detector upgrades.

The other string to Brookhaven's bow is heavy ions. Last year, work got underway to allow heavy ions to be transferred from the 16 MV tandem Van de Graaff to the AGS (see December 1984 issue, page 433). As well as the new transfer beamline, this requires modifications to existing beamlines and detectors, as well as to the AGS itself. Ten weeks of heavy ion running per year are foreseen.

Subsequently, the new AGS booster could be adapted for heavy ion work, while further modifications could allow a wider range of heavy ions (up to atomic mass 200) to be handled.

For the 1990s, the big Relativistic Heavy Ion Collider (RHIC) could be constructed in the tunnel originally made for the defunct ISA-

BELLE project. As well as building the RHIC itself, the AGS would have to be adapted for its new role as the RHIC injector.

However the particle physics content of the AGS programme is seen as continuing 'far beyond' the planned advent of the RHIC. The AGS is the world's richest source of kaons, and a programme of kaon physics would include looking for rare decays to test current ideas. Investigations of CP (charge conjugation/parity) violation, seen only in the neutral kaon system, are vital if this long-standing physics mystery is to be finally understood.

Other AGS particle physics objectives include the neutrino sector, where question marks still loom as large as ever, spectroscopy in the 1 - 3 GeV region, where important new information could yet be obtained, and the study of hypernuclei (nuclei with one or more nucleons replaced by heavier particles) to provide an additional lever on particle interactions. With polarized beams available in the AGS, the whole gamut of spin physics opens up. In addition, a new muon storage ring could be built to make even more precise measurements of the anomalous magnetic moment of the muon (see September 1984 issue, page 274).



*Well-wishers crowd the experimental area at the AGS 25th anniversary party.*

*(Photos Brookhaven)*

# Around the Laboratories

*The UA2 experiment at CERN's proton-antiproton Collider – big companion for a series of smaller studies.*

*(Photo CERN 84.9.81)*

## CERN Two more Collider experiments

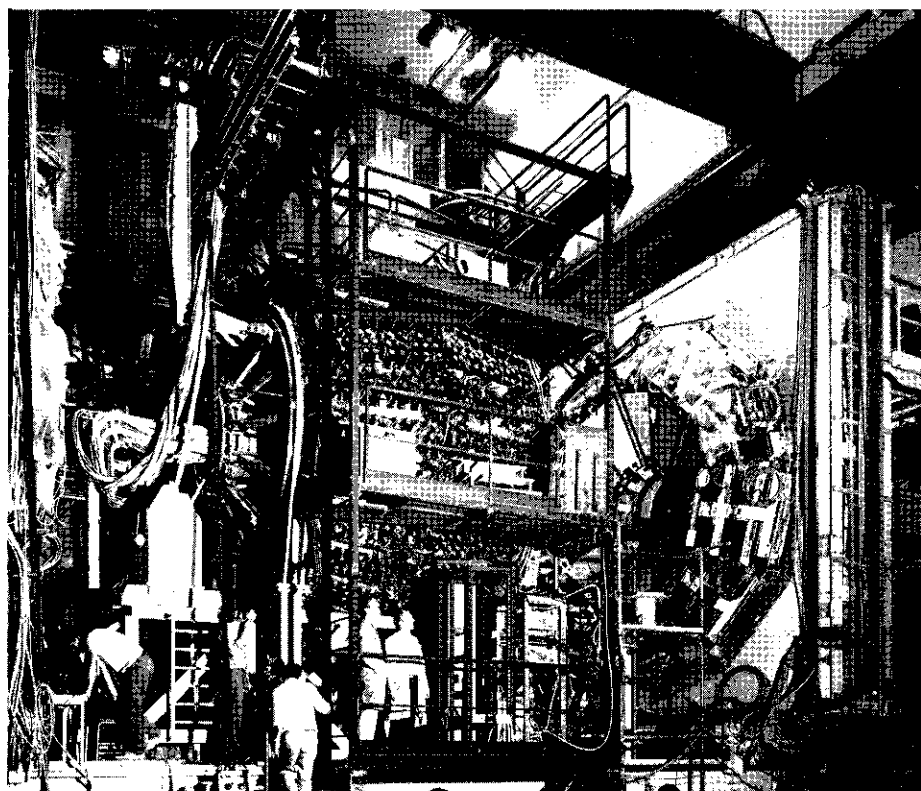
The unique physics conditions provided by the SPS proton-antiproton Collider (see also page 229) are explored by experiments mounted in the two large underground areas where the beams of protons and antiprotons are brought together.

In one underground site sits the mighty UA1 detector, described as the most complicated piece of electronics in the world. The other is the home of the UA2 detector which complemented UA1 in the famous hunt for the W and Z particles (see November 1983 issue, page 370). In this second underground area, UA2 alternates with the UA5 visual detector which provides a fast survey of new collision conditions (see May issue, page 131).

(The UA6 experiment at the Collider works in a different way, providing its own protons in the form of a jet of hydrogen gas which squirts across the path of the circulating antiprotons – see April issue, page 102.)

In the same underground area as the large UA2 apparatus is another experiment – UA4 (Amsterdam/CERN/Genoa/Naples/Pisa) – which studies elastic scattering, when the colliding protons and antiprotons 'bounce' off each other like billiard balls (see October 1984 issue, page 336).

Its initial aims accomplished, UA4 will serve as a springboard for UA7 – a brief new study this fall by a Naples/Japan group of neutral pions produced along the collision axis. The UA7 team will



install silicon/lead sandwich detectors in UA4's 'Roman Pots' to detect the photons coming from the decay of neutral pions which emerge from the proton-antiproton collisions close to the collision axis.

UA1 and UA5 have revealed interesting suggestions of new behaviour in the numbers of charged particles emerging from the collisions. These suggestions are interpreted by some as hints of the onset at SPS Collider energies of a long-awaited change of phase when matter containing particles 'boils', producing matter containing quarks and gluons (see, for example, the article by W. Willis in the January/February 1982 issue, page 179). Clues have been seen with particles coming off at large angles to the collision axis, and it is important to check if

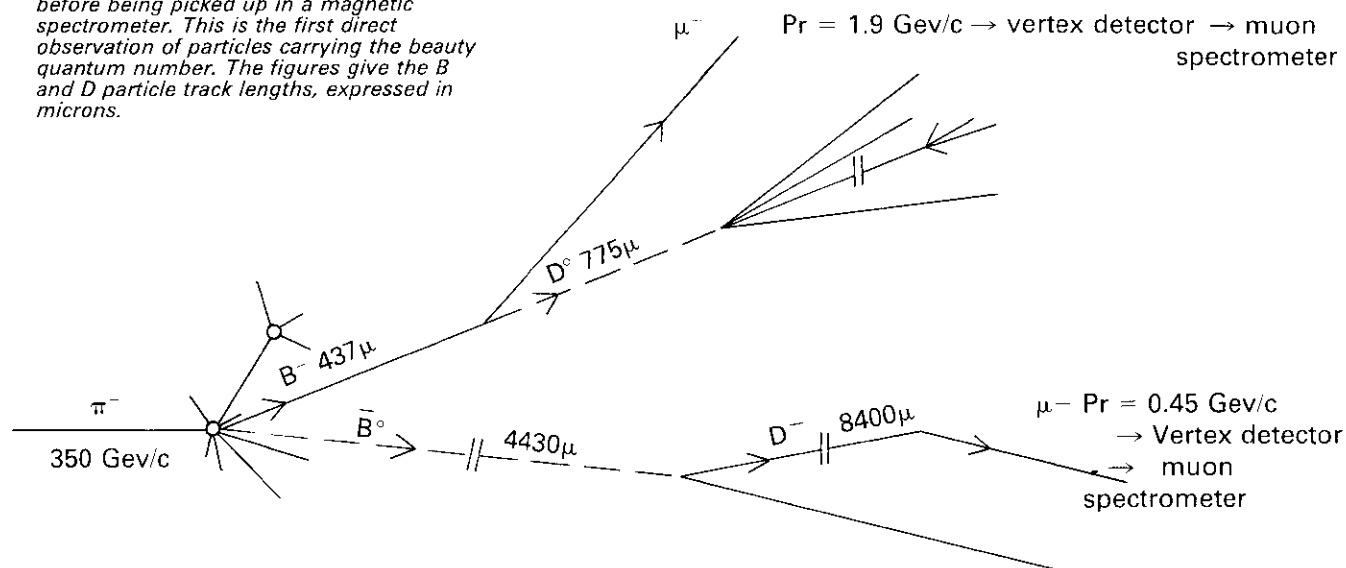
the same behaviour also occurs at small angles.

After UA7 completes its running this year, a new experiment, UA8, by a Los Angeles (UCLA) group will install a new 'mini-drift' wire chamber system in the Roman pots vacated by UA7. The UA8 team will look at the special 'diffractive' reactions which produce a fast forward proton (or antiproton) together with large transverse energy which may be in the form of 'jets'. The fast forward particle will be detected in the wire chamber system, as was done by UA4, while the transverse energy will be picked up by courtesy of UA2's large detector.

The fast forward particle most likely contains the three valence quarks (antiquarks) of the beam proton (antiproton). Therefore, the particles with transverse energy



*Beauty! Production and decay in an emulsion stack of two beauty particles,  $B^-$  and  $\bar{B}^0$ , each decaying in turn into charm particles ( $D^0$  and  $D^-$ ). The decay products are studied in a fine grain silicon microstrip vertex detector and the characteristic muons pass through 2 m of iron shielding before being picked up in a magnetic spectrometer. This is the first direct observation of particles carrying the beauty quantum number. The figures give the  $B$  and  $D$  particle track lengths, expressed in microns.*



would be produced in a 'collision' between the antiproton (proton) and what remains after the valence quarks (antiquarks) continue on their way. This remainder probably contains the so-called 'Pomeron', long believed to be the mediator of high energy elastic and diffractive interactions. (The name acknowledges Soviet physicist Y. Pomeranchuk who developed important theorems on high energy scattering.)

By studying the structure of such events at the very high energies available at the SPS Collider, the UA8 experimenters hope to open up the substructure of the mysterious Pomeron.

Appearance of electrons would signal production of heavy quark flavours (charm, beauty, etc.) in these diffractive interactions.

To efficiently select high mass diffractive events at the high collision rates which will eventually be provided by the ACOL antiproton collector now under construction, the momentum of the fast forward particle will be calculated between bunch crossings by new fast electronics.

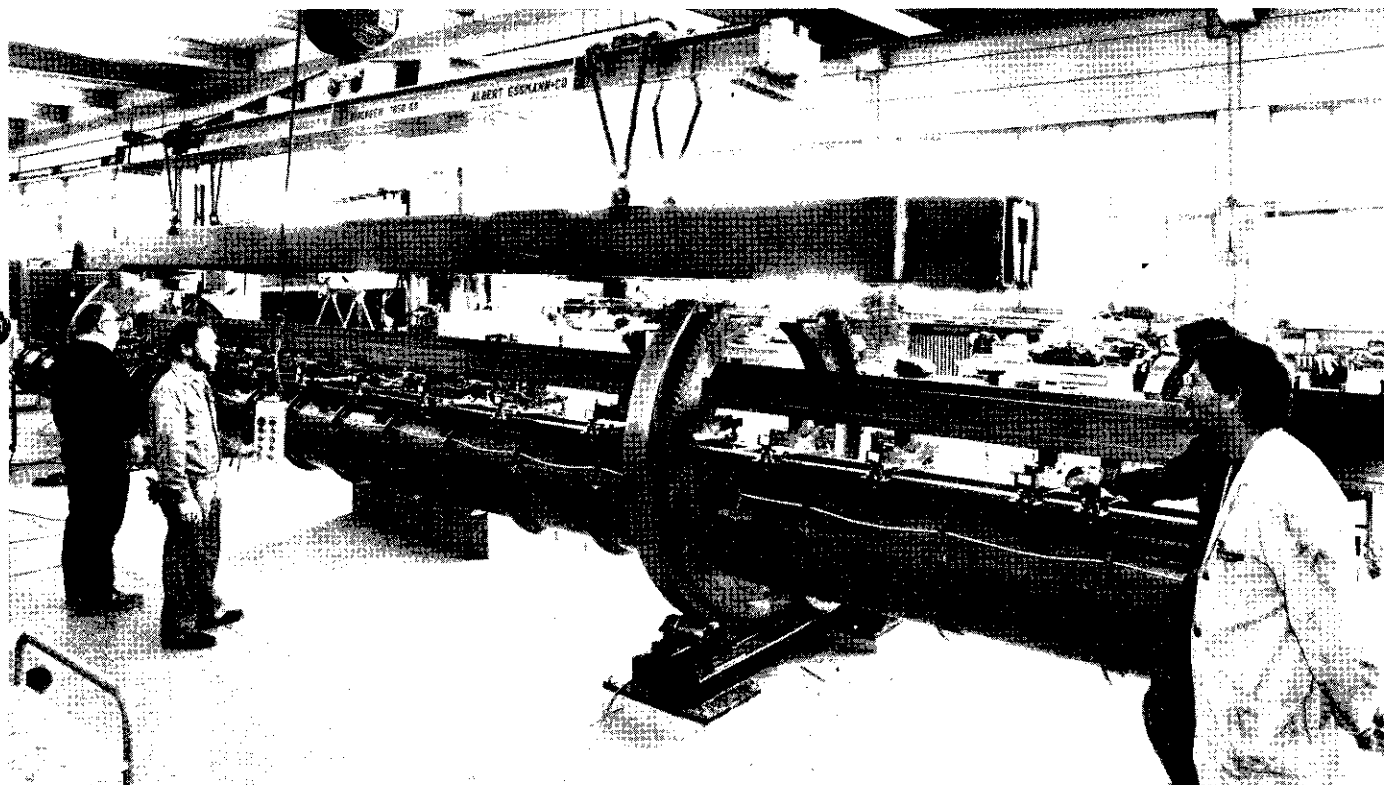
## A Beauty unveiled

*The WA75 Collaboration at CERN (Bari – Birkbeck and University Colleges London – Brussels – CERN – U.C. Dublin – Japanese Universities Groups – Rome – Turin) recently observed the decay of a pair of beauty particles ( $B$ ) both decaying into charm particles in a hybrid electronics-emulsion experiment. This is the first direct observation of such decays. Indirect observations were made previously in electron-positron rings at Stanford, Cornell and DESY-Hamburg. In the WA75 experiment, events are selected by a muon spectrometer with multiwire chambers and drift chambers placed around a big magnet. The events are studied in a vertex detector, made of 10 planes of silicon microstrips from 50 to 200 microns pitch and of multiwire proportional chambers, placed behind the emulsion target. A beam hodoscope composed of 6 planes of silicon microstrip locates the interaction in the emulsion stack to search for decays with a precision of 20 microns.*

*The event found is particularly significant since the 4 vertices of beauty and charm particles, as well as 2 like-sign muons, are observed. The calculated background for such a configuration is quite negligible. One high transverse momentum (1.9 GeV) muon is associated with the decay of one beauty particle. The other muon (transverse momentum 0.45 GeV) is associated with the decay of a charm particle. The lifetimes of the beauty particles are somewhat shorter than the average measured in previous indirect measurements ( $0.8 \times 10^{-13}$ s for the negative and  $5 \times 10^{-13}$ s for the neutral  $B$ ). Longer lifetimes have been making physicists feel less confident about their 'standard model'. As well as WA75, other CERN experiments are continuing the search for more explicit examples of beauty.*

*The first of the 416 9 metre-long bending magnets for the 30 GeV electron ring of the HERA electron-proton collider being assembled at the German DESY Laboratory.*

*(Photo DESY)*



## DESY HERA's electron ring

Work started in May on the tunnel for the new HERA electron-proton collider (see June issue, page 179), and just as soon as each tunnel section is complete, installation will start of components for the 30 GeV electron storage ring. Work for the 820 GeV proton ring will get underway later.

Work on electron ring components is thus well advanced. First deliveries of the 496 quadrupole magnets and 632 sextupoles should arrive at DESY in September and October respectively.

While the first 9 metre-long coil for the 'hybrid' superconducting magnets for the proton ring was being prepared for its cryostat at Brown Boveri, the first of the 416

9-metre bending magnets for the electron ring was assembled at DESY. These magnets will supply a field of 0.1849 Tesla, fed by a single aluminium conductor 10 cm square, running all round the 6.4 km ring. The bending magnets will be included in 12-metre modules, including also a quadrupole, one or two sextupoles and the correction magnets, all on a single support.

## CORNELL Multi-bunch operation

At its peak energy, the luminosity (collision rate) of an electron-positron storage ring is limited by the current which can be stored using the available radiofrequency power. Below the peak energy,

performance is limited by the beam-beam interaction in the ring.

The CESR ring at Cornell was designed for 8 GeV beam energy, but the physics programme has concentrated on the 5 GeV/beam region, with its rich upsilon physics. To overcome the limit imposed by beam-beam interaction, more bunches of colliding particles can be stored, which boosts the luminosity provided extra collision points can be avoided. Electrostatic separator elements are ideal for this purpose.

Multiple bunch running was implemented in CESR during the summer of 1983, and became standard practice from October of that year. Beams are electrostatically separated in the horizontal plane on either side of the interaction region. The

Plan view (not to scale) of multi-bunch operation as used in the CESR electron-positron collider at Cornell. Approximate bunch-encounter locations are indicated (solid bunches), with subsequent encounters at alternate points shown dotted. At the two interaction points for experiments (IP), the orbits coincide.

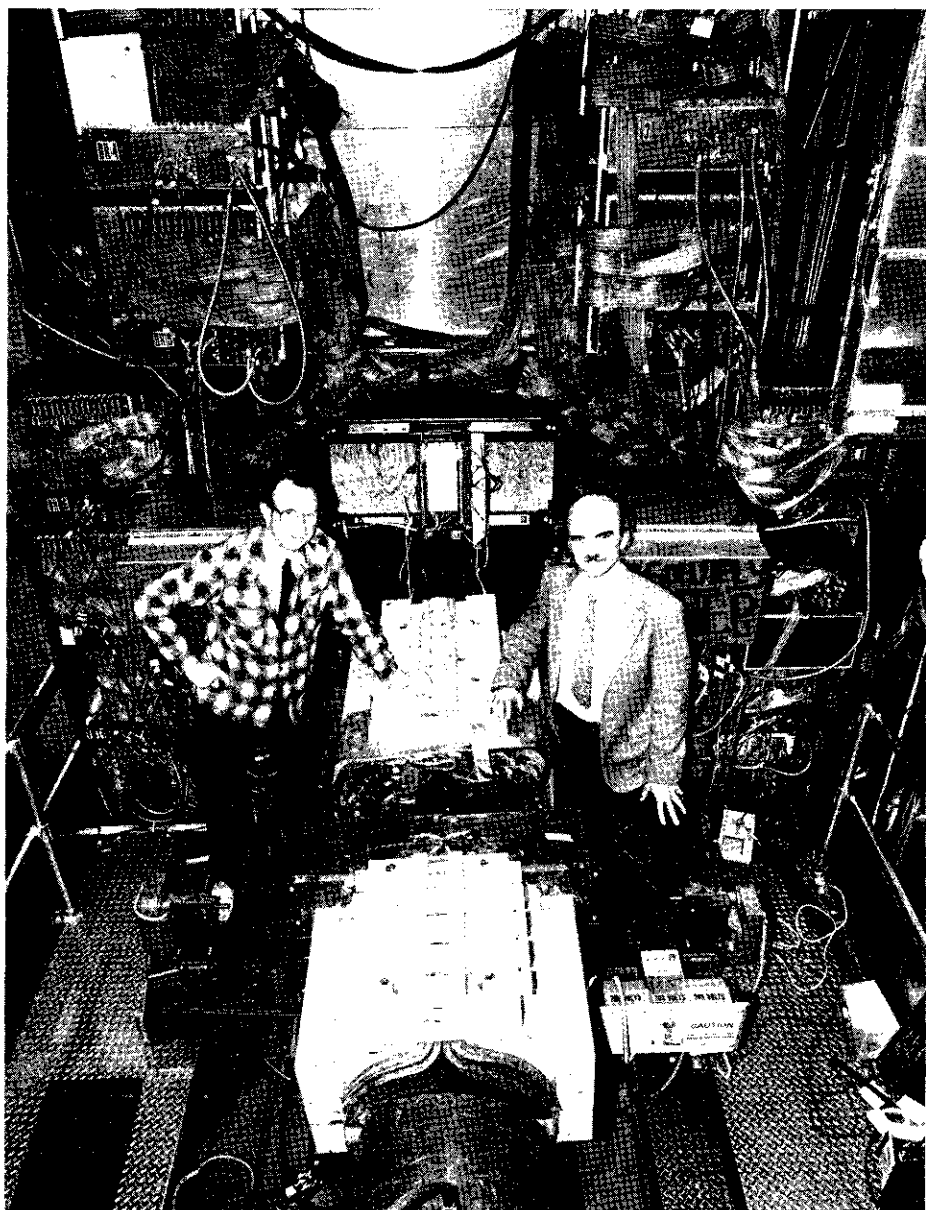
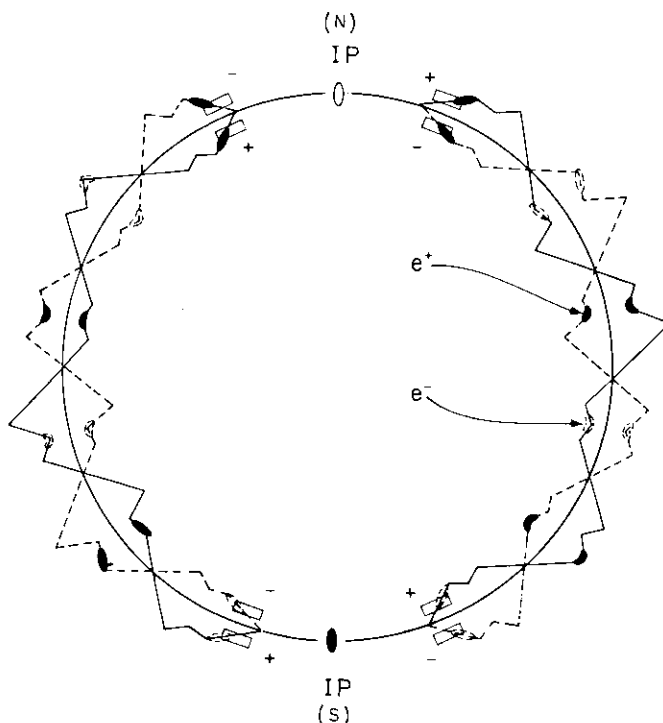
resultant 'pretzels' are phased so that the unwanted collisions coincide with maximum separation.

With CESR, it is possible to run with up to seven bunches. During the first week of seven-bunch running at the end of last year, peak luminosities attained  $3.6 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$  per interaction region and integrated luminosities of 1.4 inverse picobarns per day were recorded. This required total beam currents above 160 mA, calling for significantly more r.f. power and leading to increased higher order mode heating.

In early January, the demands of such currents on the r.f. system resulted in the failure of the cavity main power window. Although seven-bunch running has been temporarily halted pending improvements to the window, attaining such performance levels so quickly bodes well.

During 18 months of multiple bunch running, initially with three bunches and then with the maximum seven, the major limitations have been identified. These come from accelerator optics and the effects of field errors, the r.f. cavity problems mentioned previously, and new demands on the detectors.

In seven bunch running, the CLEO and CUSB detectors in the CESR ring have had to learn to trigger on bunch crossings only 365 nanoseconds apart. To handle this, new electronics have been designed and installed. In addition, the higher stored current has generally led to larger



Boyce McDaniel (left) and Karl Berkelman at the West pole of the CLEO experiment in the CESR ring. On 1 July, Berkelman took over from McDaniel as Director of Cornell's Newman Laboratory of Nuclear Studies.

# People and things

backgrounds from synchrotron radiation and degraded beam particles. After careful study, these backgrounds have been minimized by judiciously placed masks.

Looking further ahead, other improvement projects should push the luminosity to twice its present multi-bunch level. The first is to modify the injection system to provide more reliable injection. The second is to install rare-earth/cobalt permanent quadrupole magnets close to the interaction points to squeeze the colliding beams closer together. These projects should be completed in time for the arrival of the CLEO II detector (see April issue, page 106).

## Change at the top

Boyce McDaniel stepped down as Director of Cornell's Floyd R. Newman Laboratory of Nuclear Studies on 1 July. His 18 year period as Director included both the 12 GeV electron synchrotron and the CESR electron-positron collider. While on leave from Cornell in 1972, he served as head of the Accelerator Division at Fermilab during the commissioning of the (then) 400 GeV accelerator. McDaniel is a member of ICFA (International Committee for Future Accelerators), and is chairman of the Board of Overseers for the US Superconducting Super Collider (SSC) project. He continues as Cornell Professor of Physics.

New Cornell director is physicist Karl Berkelman.

## Future of CERN

Under the chairmanship of Carlo Rubbia, a 'Working Group on the Scientific and Technological Long-term Future of CERN' has been set up 'to explore various options for the long-term future of CERN, taking into account existing facilities (infrastructures), emphasizing respective pros and cons; in working out these options, realistic boundary conditions concerning financial and manpower limitations should be taken into account.' Members of the Group are Giorgio Brianti (CERN), Pierre Darriulat (CERN), Gösta Ekspong (Stockholm), Carlo Rubbia (Chairman), Abdus Salam (London and Trieste), Samuel C. Ting (MIT), Simon van der Meer (CERN), and Gus Voss (DESY). ECFA Chairman J. Sacton will attend the meetings of the Group as an observer. The first meeting took place on 5 June.



Carlo Rubbia — looking at the long-term future of CERN.

## Heavy neutrino?

A big question mark still looms over the mass of the neutrino. Is this particle truly massless, moving at the speed of light, or has it some small mass? For some time, bench-top experiments in Moscow and elsewhere studying beta decay have been suggesting that the electron-type neutrino weighs somewhere in the region from 20 to 45 eV.

One sensitive test for neutrino mass effects is the shape of the electron emission spectrum measured in beta decay. The detailed shape of the spectrum at the high energy end is governed by the mass of the electron-type neutrino. In a recently published result, John Simpson of the University of Guelph, Ontario, Canada, reports instead a distortion at the low energy end of the beta decay spectrum of tritium. Simpson, who has been studying tritium decay for four years, interprets this as being due to a heavy (17.1 keV) neutrino.

Such a mass, although very light compared to other particles (the lightweight electron is 511 keV), is unparalleled in neutrino circles, and will be sure to set the theorists thinking.

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#### *Constant Tièche*

*Constant Tièche, retired head of CERN Finance and architect of much of CERN's financial administration, died on 27 May.*

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#### *Mervyn Hine retires*

*Mervyn Hine, one of CERN's founder members, retired at the end of May. He came to the Laboratory, together with the late John Adams, in 1953 and played a leading role in the design, construction and commissioning of the 28 GeV Proton Synchrotron.*

*On completion of the machine, he began a ten-year period of major responsibility in the CERN hierarchy working with Directors General Adams, Weisskopf, Gregory and Jentschke. Viki Weisskopf, in particular, paid tribute to Hine as being the powerhouse behind the work of the CERN management at that time.*

*He has contributed to accelerator development, to project presentations, to establishing financial procedures and to promoting developments in the Laboratory infrastructure (like the use of big computers, networks, high speed data links and office automation). His thinking and his forward vision have helped CERN to be ready when 'the future' arrived.*

*Mervyn Hine is one of the pioneers who created CERN and who helped forge its particular character from which the Laboratory is now reaping the benefit.*

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*Mervyn Hine*

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#### *ATLAS at Argonne*

*ATLAS, short for Argonne Tandem Linear Accelerator System and the world's first superconducting heavy ion accelerator, was dedicated at the US Argonne National Laboratory on 3 June.*

*The new linac boosts the energies of particles emerging from a tandem Van de Graaff and provides a useful extension to the range of nuclear physics studies at Argonne. Similar machines are under construction at Florida State and Kansas State Universities.*

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#### *French Academy of Sciences*

*Detector specialist Georges Charpak of CERN was recently elected a member of the prestigious French Academy of Sciences.*



*Georges Charpak*







The nuclear physics section of NIKHEF, the Netherlands' National Institute for Nuclear and High-Energy Physics, has openings in the PIMU group for

## TWO EXPERIMENTAL PHYSICISTS

at the postdoc level, who are interested to participate in the research of the group on pion absorption in nuclei and on pion charge exchange in pionic atoms. The experiments are performed at the pion/muon facility in Amsterdam and in some cases abroad.

Several years of research experience in nuclear or (intermediate energy) particle physics are required, while a strong background in particle detection techniques and/or data processing (hardware/software) is desirable.

The duration of one contract is two years. For the other one it is one year with a possibility of one year prolongation. The appointment will be with the Foundation for Fundamental Research on Matter (FOM).

Information can be obtained from Dr. R. van Dantzig, tel. (020) 5920120 or 5922008.

Candidates are invited to apply within two weeks after appearance of this advertisement, while enclosing a curriculum vitae, also mentioning performed research and names of referees, to

**Prof. Dr. G. van Middelkoop,**  
Scientific Director of NIKHEF,  
section K, Postbox 41882,  
1009 DB Amsterdam, Netherlands.



European Organization for Nuclear Research  
European Laboratory for Particle Physics  
Organisation Européenne pour la Recherche Nucléaire  
Laboratoire Européen pour la Physique des Particules

The Experimental Physics Division intends to make an appointment to the position of a

## PHYSICIST

in experimental particle physics research. Candidates are expected to have an excellent record of successful work in this field, and to have the ability to provide leadership. The appointment will be made for a fixed term, and may subsequently become permanent.

The holder will play an important role in all aspects of the conception and design of experiments, and of the construction and operation of detectors, and the development of on-line and off-line software and the analysis of data.

Please send letters of application, including the names of three referees, list of publications, a brief curriculum vitae and a brief description of research interests, to the

**Leader of the Experimental Physics  
Division,  
CERN, 1211 Geneva 23, Switzerland  
quoting reference EP/RE, before 5.8.85.**

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LAWRENCE BERKELEY LABORATORY,  
Employment Office, One Cyclotron Road,  
Building 90, Room 1012, Berkeley, CA 94720.**

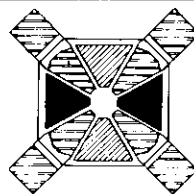
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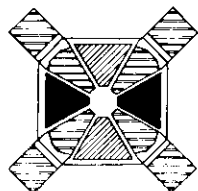
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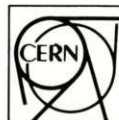


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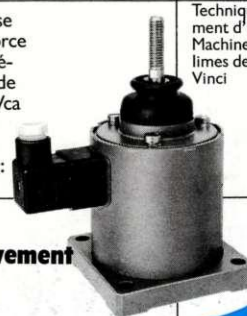
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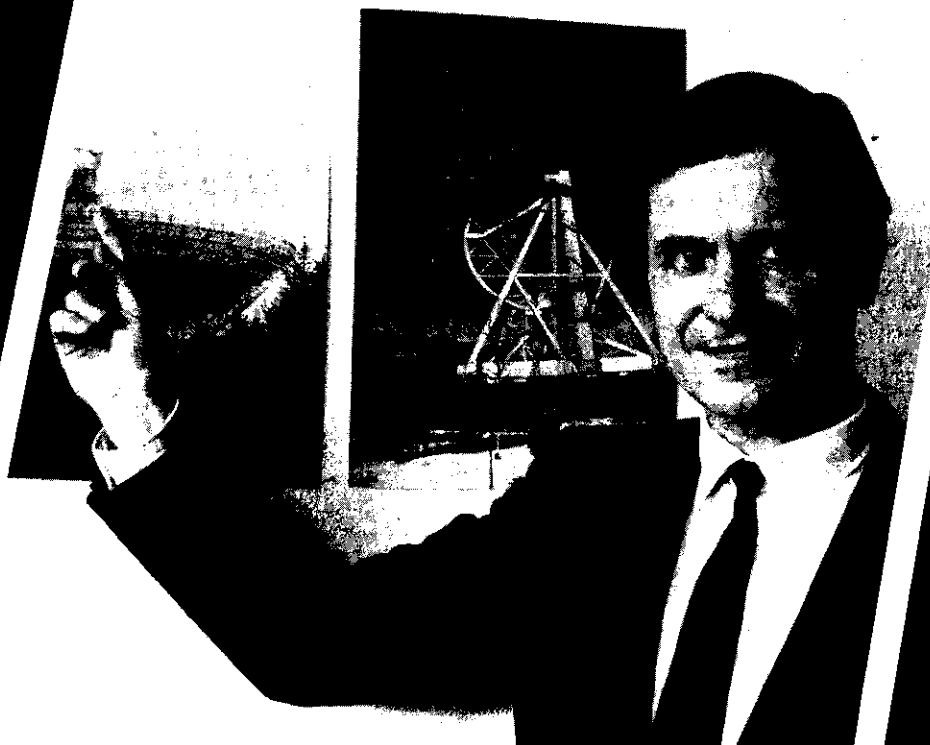


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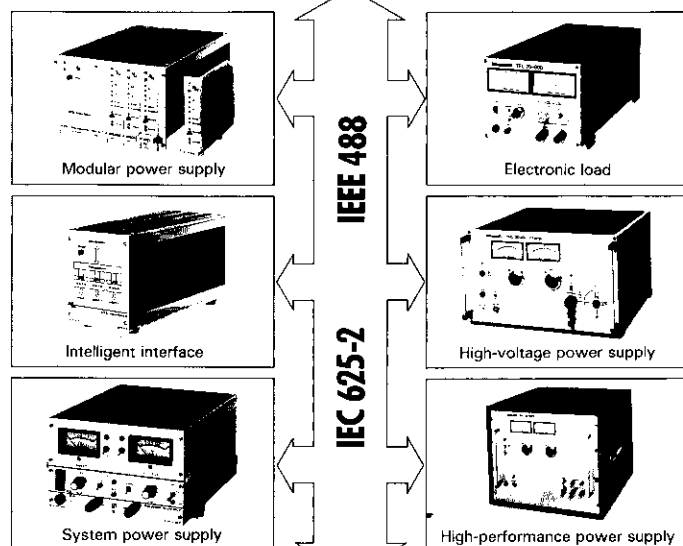
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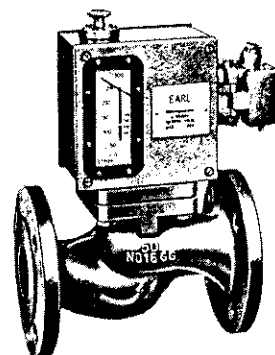
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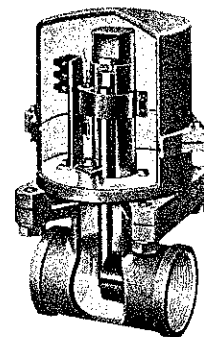
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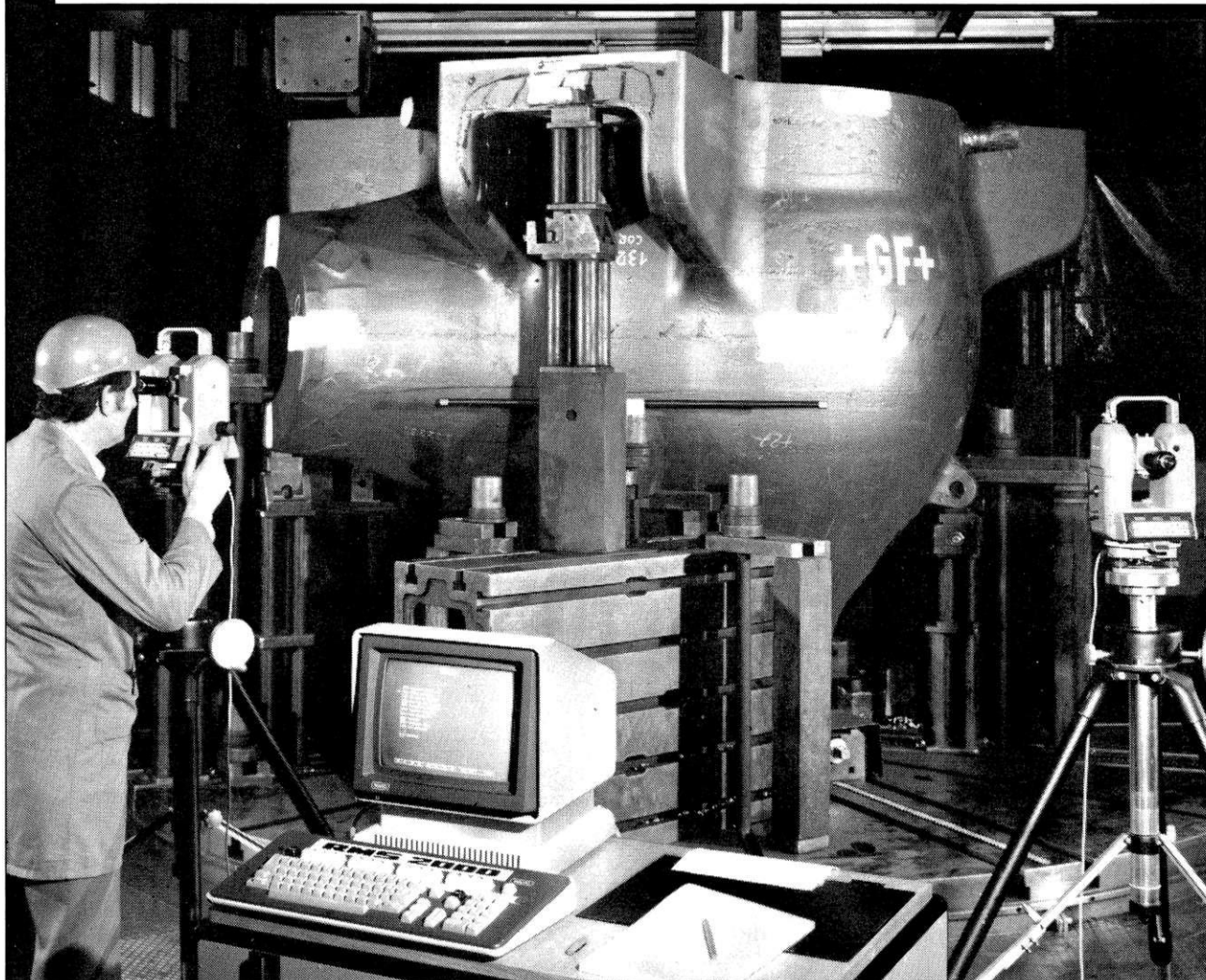
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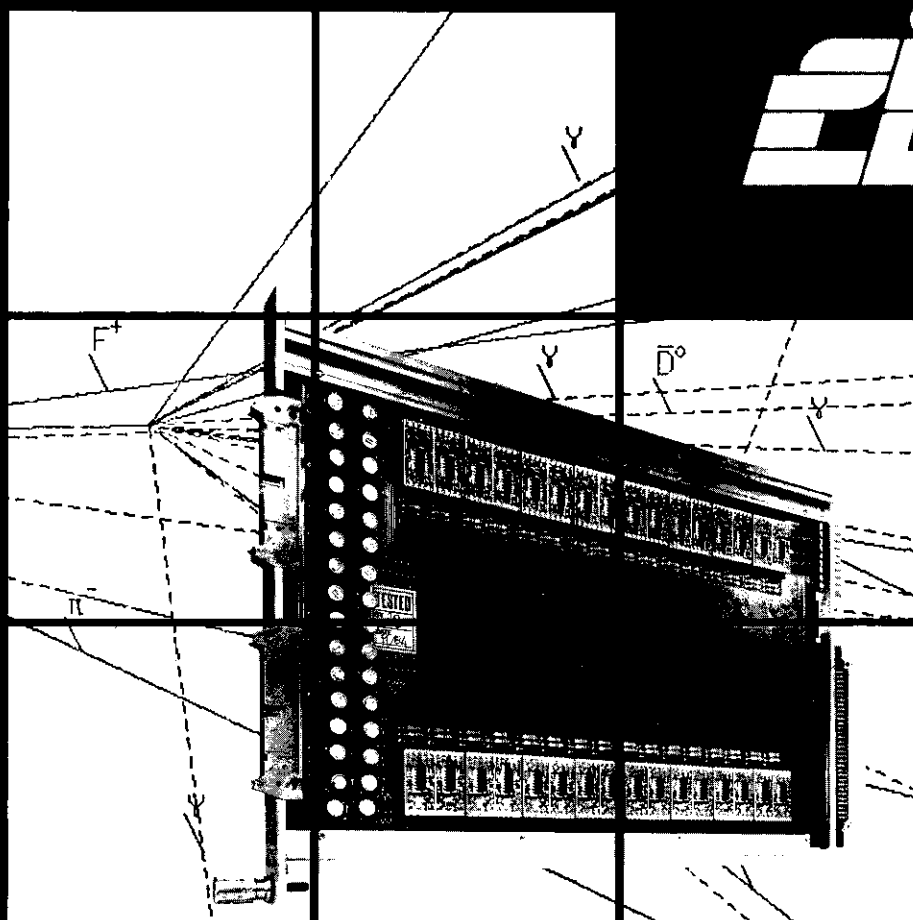
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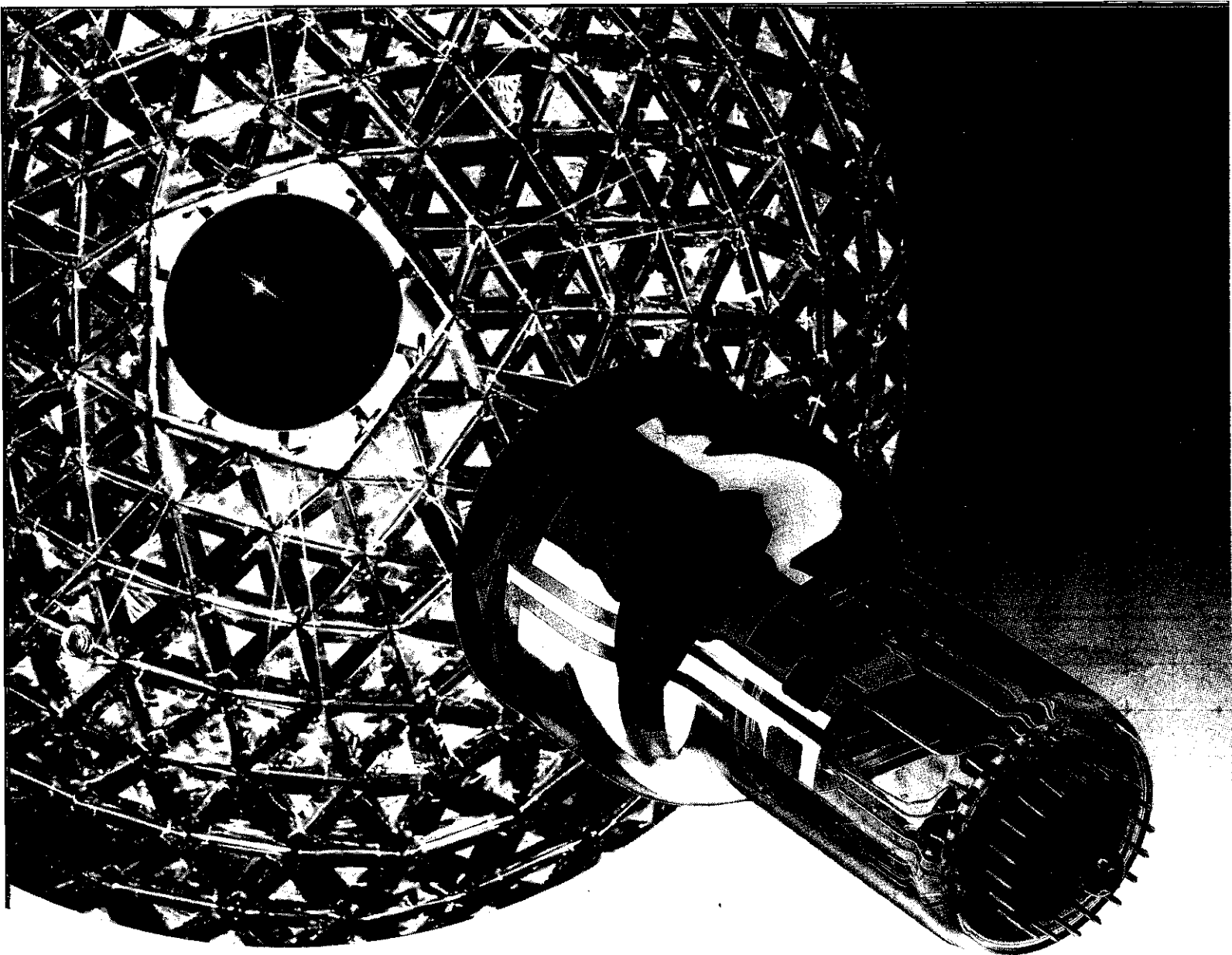
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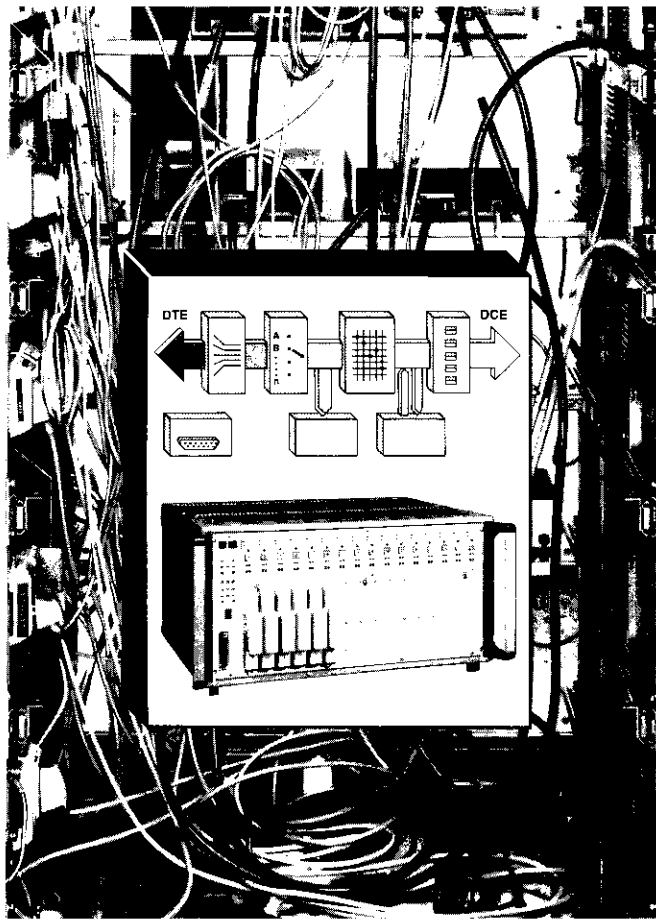
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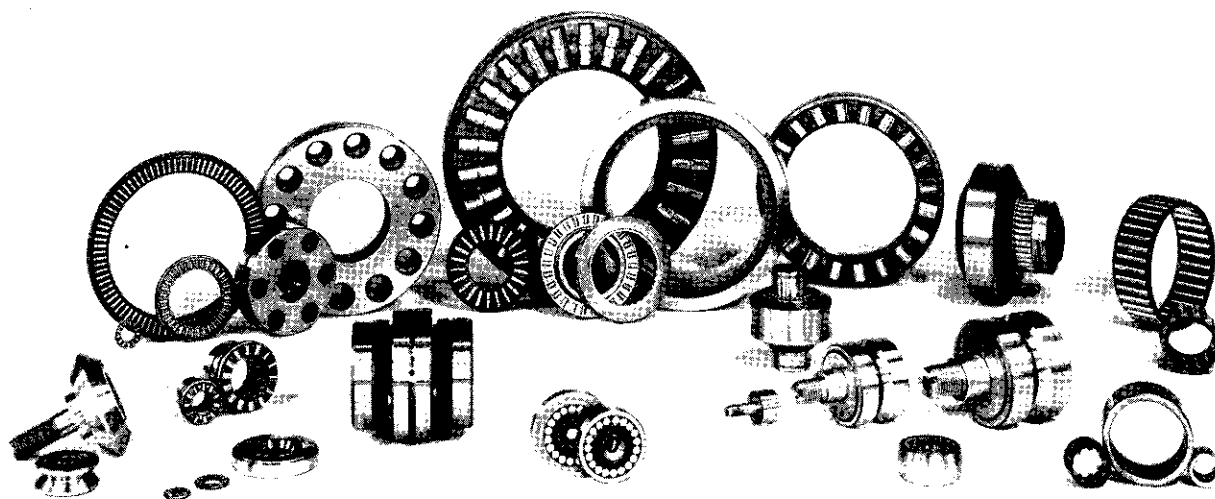
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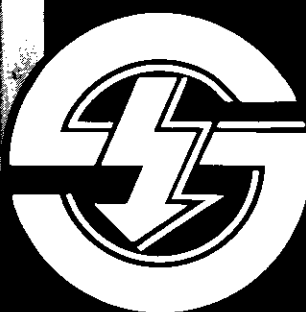
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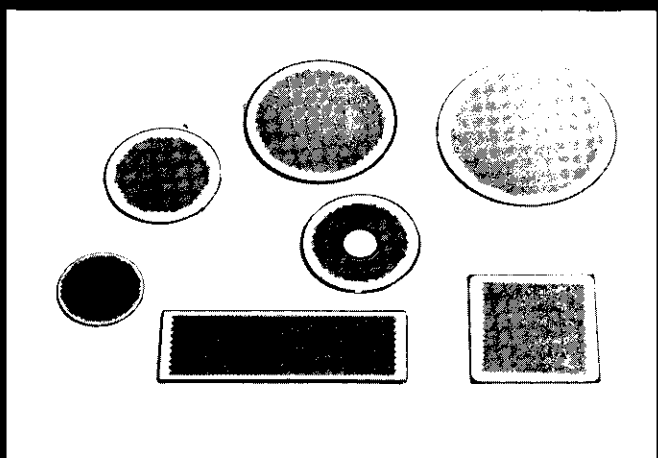
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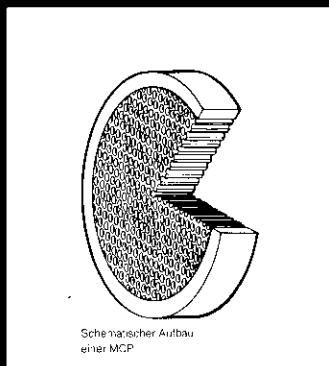
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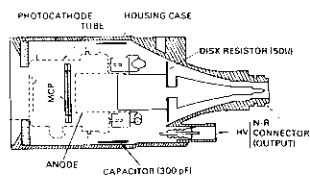


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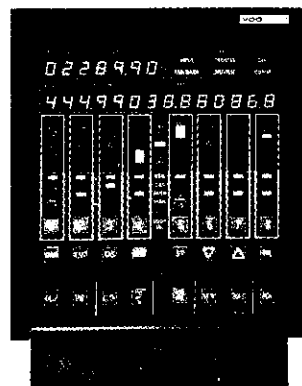
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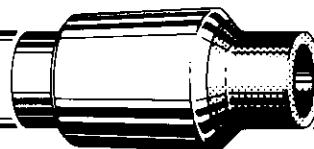
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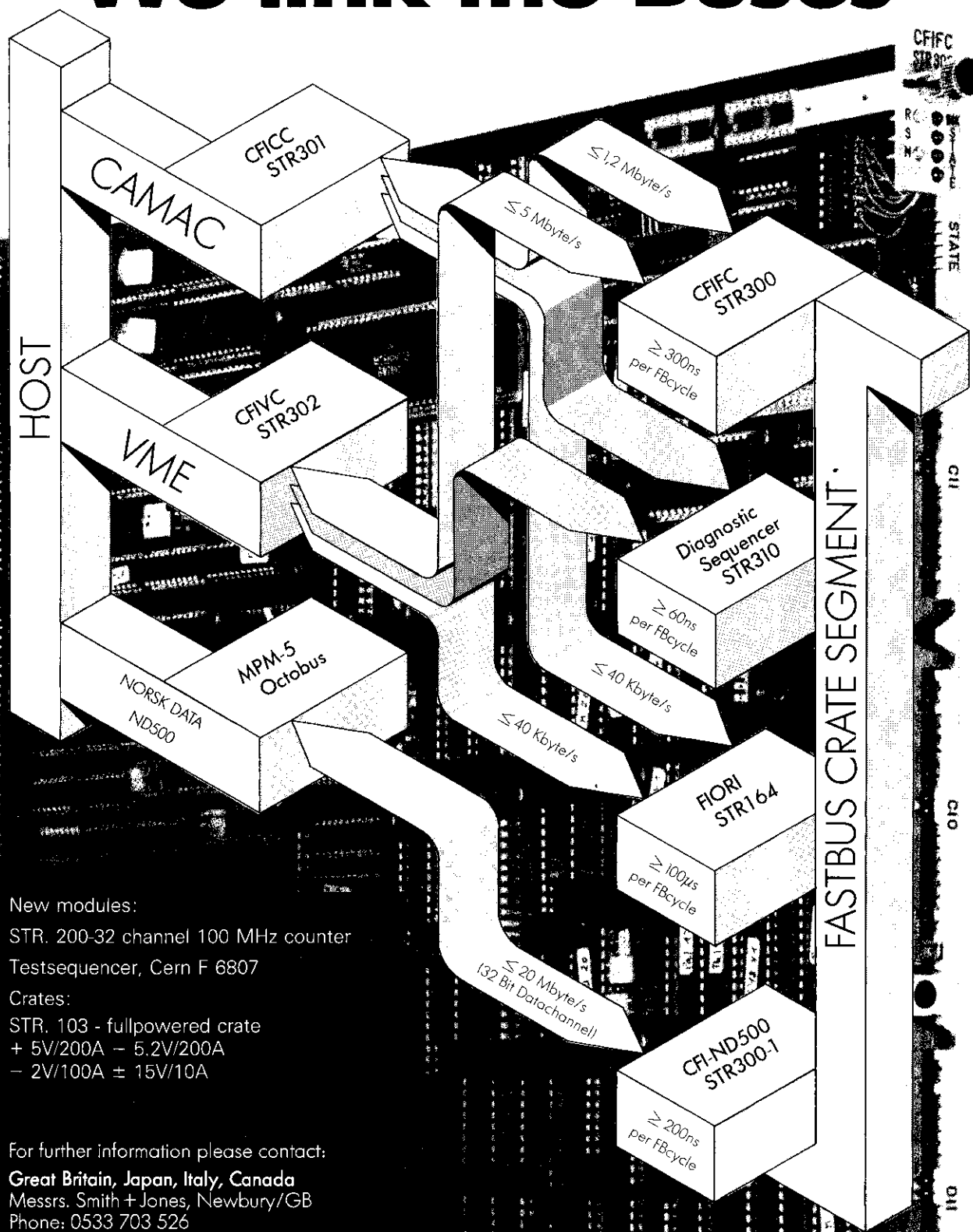
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# New standards of efficiency for Gamma Spectrometry

The 9256 photomultiplier sets a new standard for energy resolution, linearity and collection efficiency. With its new D400 electron optical design, high efficiency bialkali photocathode and a rise time of 2.5 ns, this tube is suitable for most scintillation counting applications, including those using plastic scintillators.

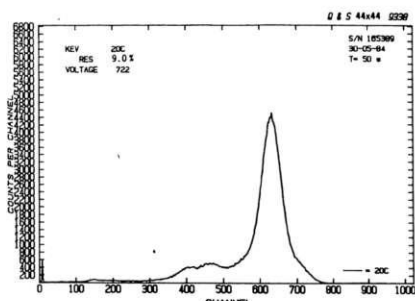
This tube is the first in a series where the main

benefit will be in gamma spectrometry, gamma cameras and counting assemblies.

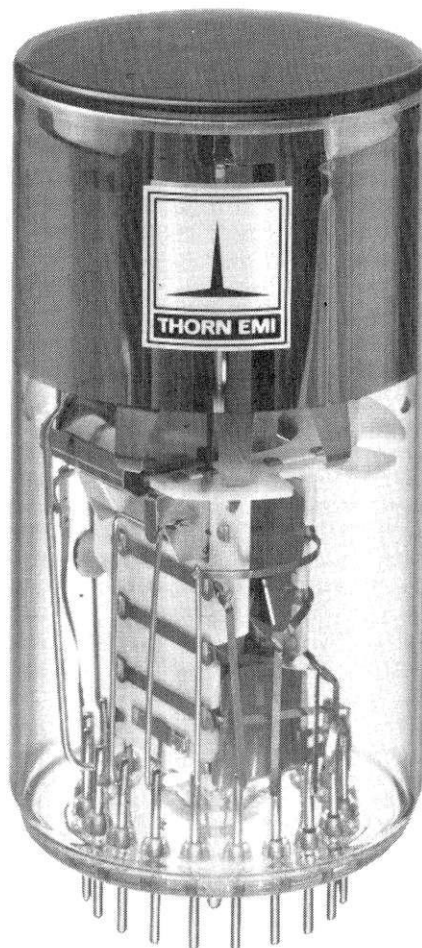
The 9256 is 52 mm in diameter, and is directly interchangeable with the established THORN EMI 9956.

Contact THORN EMI or local representative to find out how this new photomultiplier can benefit your application.

- Pulse height analyser spectrum for  $^{57}\text{Co}$ .



- Pulse height resolution: 6.8% for  $^{137}\text{Cs}$ , 9.0% for  $^{57}\text{Co}$ .
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