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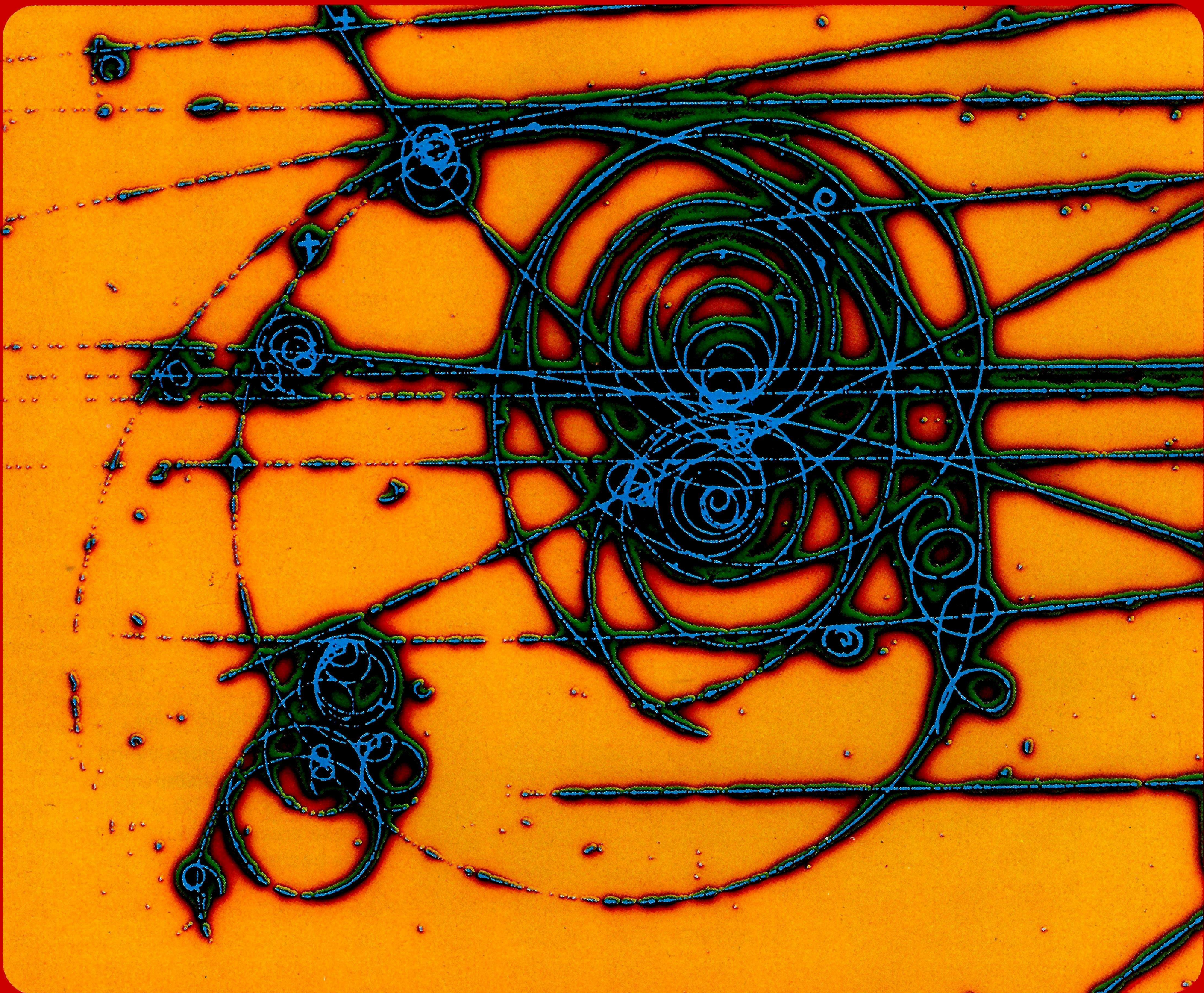

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Copies are available on request from:
Federal Republic of Germany —
Frau G. V. Schlenther
DESY, Notkestr. 85, 2000 Hamburg 52
Italy —
INFN, Casella Postale 56
00044 Frascati
Roma
United Kingdom —
Elizabeth Marsh
Rutherford Laboratory, Chilton, Didcot
Oxfordshire OX11 0QX
USA/Canada —
Margaret Pearson
Fermilab, P. O. Box 500, Batavia
Illinois 60510
General distribution —
Monika Wilson
CERN, 1211 Geneva 23, Switzerland

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CERN COURIER

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VOLUME 22 N° 4 MAY 1982

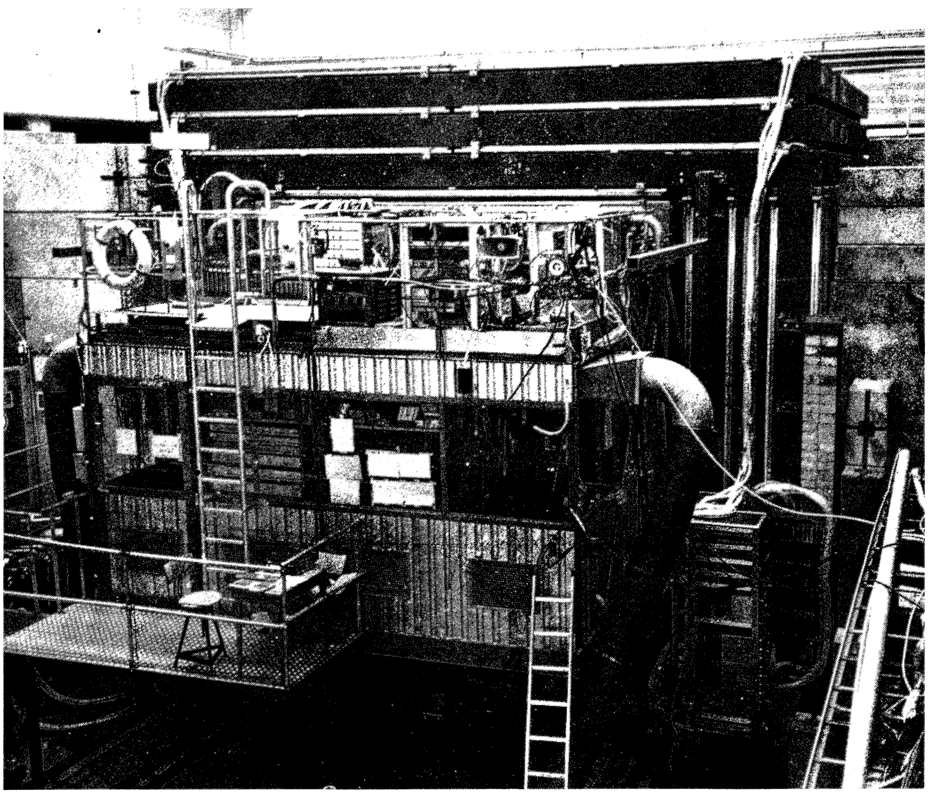
Around the Laboratories

Cover photograph: In the skilful hands of Patrice Loïez at CERN, a detail from a BEBC bubble chamber photograph becomes a work of art. The same photograph, reproduced in different colours, was used in the t-shirt design for last year's European particle physics conference at Lisbon (see September 1981 issue, page 287).

Measuring electroweak interference

The JADE detector at the PETRA ring at DESY, surmounted with concrete slabs of muon filter.

(Photo E. & P. Hamburg)

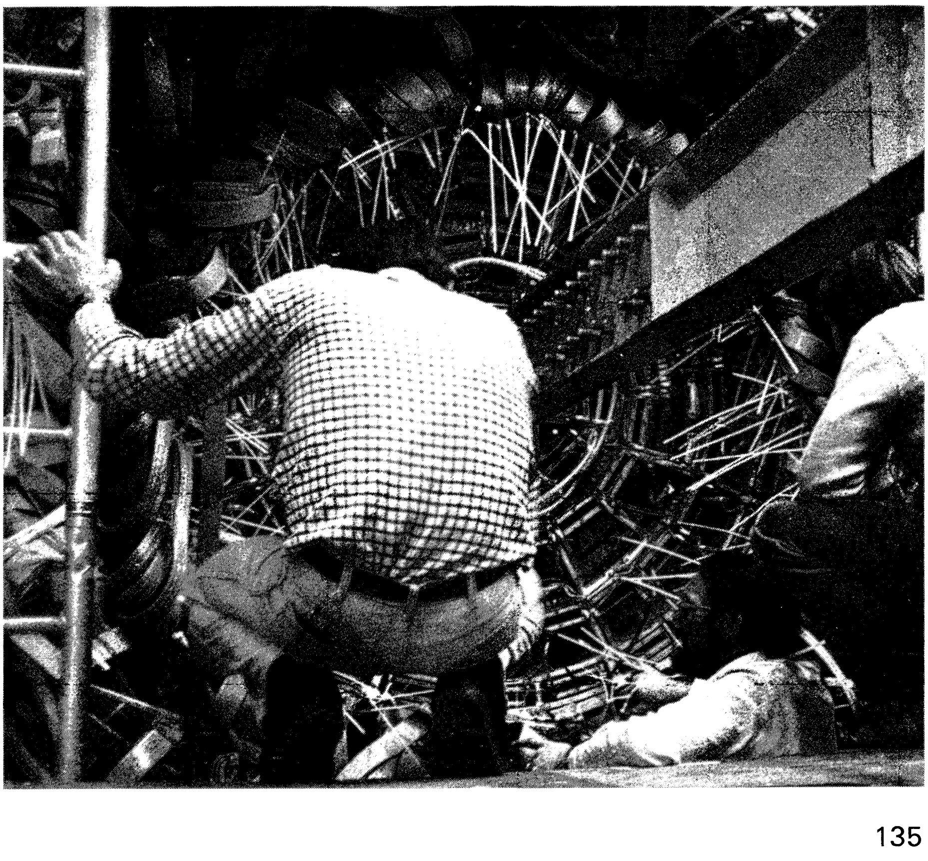


The delicate interference effects of weak and electromagnetic interactions provide a vital check on current gauge theory ideas which unify the electromagnetic and weak forces.

First results on this interference measured in electron-positron annihilation were presented at last year's conference in Bonn (see October 1981 issue, page 350). Since then, new data have been collected by all experimental groups working at the PETRA storage ring at DESY. The statistics are now much improved, mainly due to the higher event rates achieved at PETRA. Much of the improvement can be attributed to the mini-beta focusing system (see July/August issue, page 237) which tripled the available luminosity.

New electroweak interference results have now been published by the JADE and TASSO groups. In addition, CELLO and Mark-J presented preliminary new results at the recent particle physics meeting of the German Physical Society at Karlsruhe. All these results measure the production of lepton pairs in electron-positron annihilation.

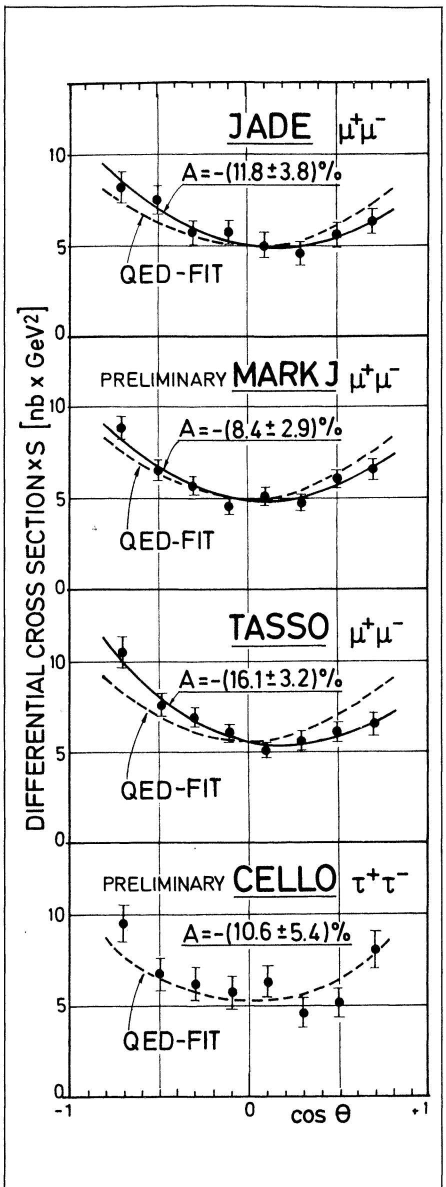
Tiny electroweak interference effects (about 0.01 per cent) have been seen in atomic physics experiments and at SLAC in polarized electron scattering. However according to the currently accepted gauge theory ideas, the strength of the weak force increases as the square of the momentum transferred in the interaction. The earlier studies involved only small momentum transfers. However in electron-positron annihilation the momentum transferred is the sum of that of the colliding particles. At PETRA, this attains a significant fraction of the predicted mass



The large cylindrical drift chamber being replaced in the coil of the superconducting magnet of the CELLO experiment at PETRA in readiness for the next experimental run.

(Photo DESY)

The experimental groups at the PETRA electron-positron ring are now homing on the electroweak asymmetries seen in the production of lepton pairs. This shows some of the angular distributions which have been observed.



of the Z°, the neutral carrier of the weak interaction.

At lower collision energies, say less than 20 GeV, electrons and positrons annihilate mainly through a one-photon state of definite parity and the annihilation products should therefore be distributed symmetrically about the beam axis. At higher energies, the Z° is also available as an annihilation channel, and its interference with the one-photon mechanism gives rise to the observed asymmetries. At PETRA energies, these effects, measured in angular distributions of pairs of muons and of tau leptons, attain the 10 per cent level. In principle similar effects should also be present in hadronic final states.

An important complication is due to the emission and exchange of additional photons ('radiative corrections'). Such processes introduce asymmetries by themselves and calculations show that they should amount to a few per cent. They favour final states in which the electric charge maintains its original direction (positive asymmetry). To take account of this, experimentalists have used the formulae derived by Berends and Kleiss, who calculate the required corrections to the single photon mechanism to third order in quantum electrodynamics. Future results will also have to take account of weak effects.

group	particle pairs	collision energy	asymmetry (per cent)	theory (per cent)
CELLO	muons	34.2	− (6.4 ± 6.4)	−9.1
CELLO	taus	34.2	− (10.6 ± 5.4)	−9.2
JADE	muons	33.5	− (11.8 ± 3.8)	−7.8
Mark-J	muons	34	− (8.4 ± 2.9)	−9.5
TASSO	muons	34.2	− (16.1 ± 3.2)	−9.2
TASSO	taus	34.2	− (0.4 ± 6.6)	−9.1

Although these special asymmetries are discernable, total particle production rates (summed over the full angular range) show no measurable effects and closely follow the predictions of quantum electro- and chromodynamics for lepton and quark (hadron) production respectively. Hadron production would be boosted as the Z° is approached and it is expected that this should become noticeable even at the upgraded PETRA energies scheduled in the next two years. The present total cross-section data already provide a lower limit on the Z° mass.

The measured asymmetries are presented in the accompanying table. Systematic errors have been carefully studied by all groups who present convincing arguments to show that their muon identification and in particular their charge assignments are correct. With 17 GeV muons, the distances which have to be measured are smaller than 1 mm and a confusion of sign cannot be excluded. Small deformations in the big wire chambers used to measure curvature could also introduce artificial asymmetries. Experiments use different schemes to confirm their measurements.

The underlying theory looks in good shape, but as the experimental errors are pared down, interesting implications begin to emerge. Already a Z° mass of less than 50 GeV can be confidently excluded. The results are giving a preview of the electron-positron annihilation results from higher energy machines, not least at PETRA itself, where asymmetry effects are expected to be 70 per cent bigger at higher available collision energies.

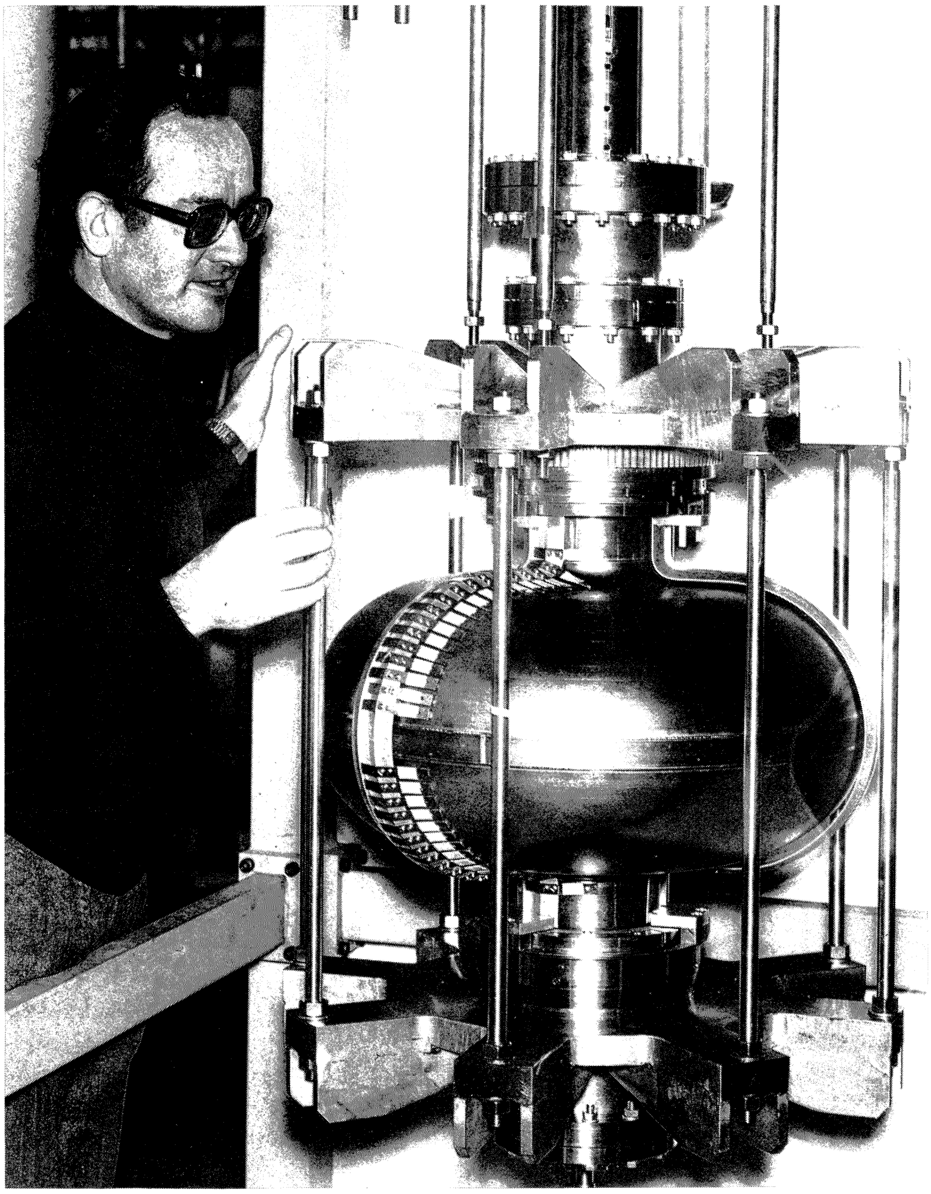
Progress on r.f. superconducting cavities

For many years research and development has been going on which has aimed to produce superconducting cavities for use in radiofrequency (r.f.) accelerating systems. The aims of this work are rather obvious. Firstly, superconducting cavities can have energy losses some hundred thousand times less than in the conventional copper wall cavities. Secondly, superconducting cavities can allow higher accelerating field gradients. Compared to conventional cavities where the gradient is usually close to 1 MV per metre, superconducting cavities can give over 3 MV per metre in c.w. mode.

These advantages have attractions in two areas. For electron-positron storage rings with high energy consumption, like LEP for CERN, the only acceptable way to reach the peak achievable energies seems to be via a superconducting r.f. system. Thus it is unlikely that LEP energies will climb beyond the Phase I level of 50 GeV without the installation of superconducting cavities. (Because of the need to compensate for the high level of synchrotron radiation at LEP energies, the r.f. losses in the accelerating cavities become the major source of energy consumption rather than the storage ring magnets.) Alternatively, for an existing storage ring of fixed size, such as PETRA at DESY or PEP at Stanford, the only way to go to higher energies is to achieve high accelerating gradients in the r.f. cavities which would again lead to the use of a superconducting system.

These interests have become more prominent recently as electron storage ring energies have increased and as a result more resources are being applied to research and development programmes. We concentrate here on progress related to storage rings leaving aside the contributions which have come from work on linear accelerators and r.f. separators.

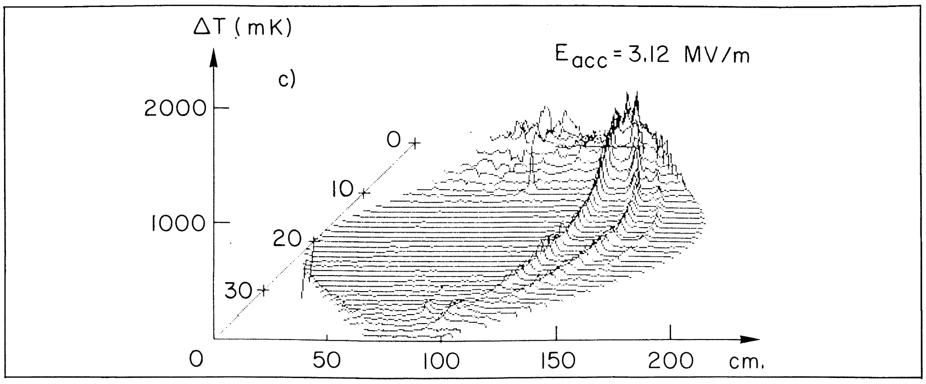
At Cornell, a test superconducting cavity was installed in the electron synchrotron as early as the mid 1970s (see June issue 1976, page 219). It was an eleven cell 'muffin tin' structure which gave encouraging results but was troubled by such problems as multipacting and surface contamination. With the recent proposal to build the CESR II 50 GeV



A single cell superconducting r.f. cavity at CERN mounted for insertion into its cryostat. Note the spherical structure (developed at Wuppertal) which has eliminated multipactor, and the line of temperature mapping resistors on the outside (left). This mapping device has made it possible for the first time to identify with precision the local regions where losses occur. Tests with such single cells have considerably advanced the understanding of superconducting r.f. cavity behaviour.

(Photo CERN 3.12.79)

A 'geographical' map of a single cell array obtained by temperature monitoring. The 'mountains' are regions of increased r.f. losses (two ridges due to electron loading and an isolated peak at a region with strongly increased r.f. loss).



storage ring at Cornell, the work has been taken up again in earnest. The muffin tin structure is being retained and a new test in the existing CESR storage ring is imminent.

Karlsruhe has also had a long tradition in superconducting r.f. and is preparing a test installation in the PETRA storage ring at DESY. A cylindrical cell structure is being used in which field gradients of 2.5 MV/m have been reliably achieved in bench tests at 500 MHz. DESY is building up a group to work on this topic with a view to higher energies and lower energy consumption in PETRA operation. 500 MHz cavities have also been adopted by the KEK Laboratory in Japan whose interest is related to the TRISTAN storage ring. First results were reported in the January 1981 issue (page 16) and 6.5 MV/m has recently been achieved in a single cell.

In the context of the LEP project, CERN started a feasibility study in 1979. The work has been carried out in association with European Universities — Geneva, Genoa, Paris and Wuppertal — and in close contact with DESY and Karlsruhe. The Wuppertal experience was particularly helpful (they have their own superconducting linac project in collaboration with Darmstadt). Within CERN, expertise has been available in workshop techniques (thin sheet metal work, electron beam welding, brazing, surface treatments, electron microscopy) and in r.f., cryogenic and vacuum technologies.

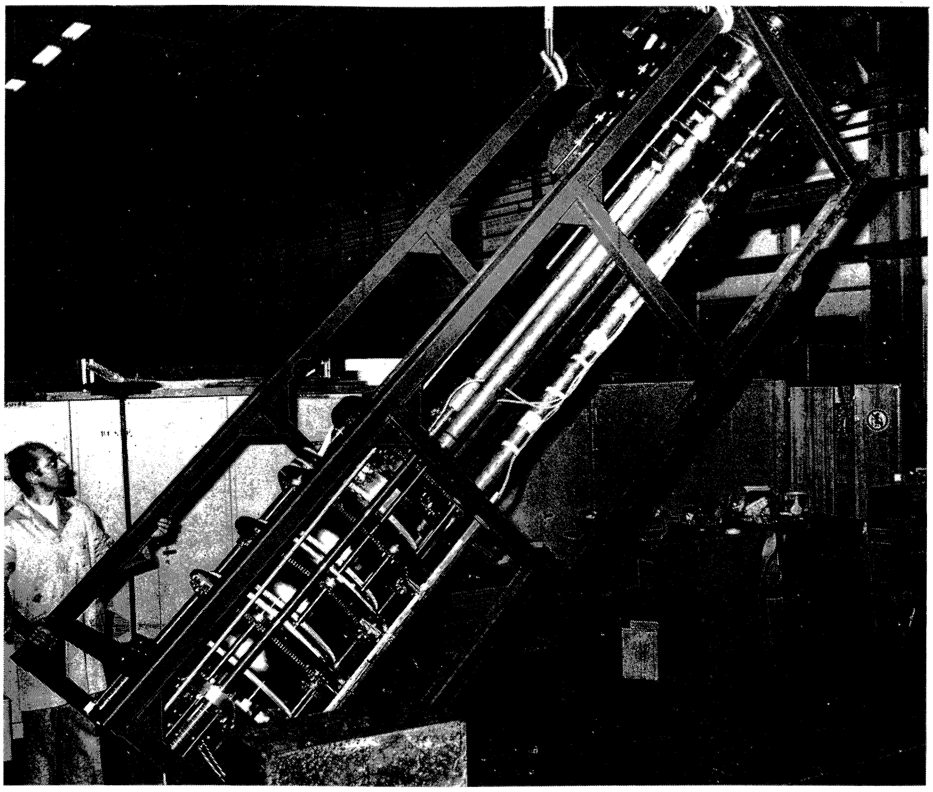
Two factors have been particularly important. Firstly the adoption of the spherical design has virtually removed the phenomenon of multipacting (an electron resonance phenomenon in cavities, causing losses and breakdown). Also the spherical shapes are easy to machine (spinning from sheet niobium) and to surface treat, which would help to keep costs reasonably low in subsequent mass production.

The second factor has been the use of a temperature mapping device which can monitor temperatures locally all over the cavity. This has made it possible for the first time to 'see' (by identifying the position of a temperature rise) where losses in the cavity are taking place. These losses are due to electron emission or are poorer quality regions of the cavity giving r.f. losses which can lead to breakdown.

The problem of electron emission has been mastered by helium ion sputtering at low temperature. With this source of loss removed, the region of r.f. loss can be localized and 'dental surgery' can be used to clean up the surfaces in the affected regions (removing iron inclusions, dust, etc.).

Using these techniques, single cell performance has increased to give a voltage gradient of 6.5 MV/m with a Q factor of 3×10^9 (which corresponds to losses of about 5 W/m at a gradient of 3 MV/m). A four cell structure gave 2.8 MV/m and a Q of 1.7×10^9 on its first test. This performance was not pushed further since attention has been concentrated on thorough understanding of the phenomena occurring in single cells. However now that this understanding seems to be satisfactory, attention is returning to multicell cavities.

In addition, the introduction into the cavity of all the necessary facilities which will be needed for operation in a storage ring has been pro-



A four cell structure being prepared for its cryostat. First performance was encouraging and further tests to improve voltage gradient and the Q-factor are scheduled soon.

(Photo CERN 311.12.80)

gressing well. Tuners, higher order mode couplers, power input couplers and cryostat designs have been tried and are ready for application in an actual cavity.

The next major step is the installation of a five cell cavity in PETRA at DESY, probably at the end of this year. This cavity, 1.5 m long, will be amongst the biggest ever tested in an actual storage ring environment. There is also interest in having a superconducting r.f. unit installed in LEP from the early days of operation so as to prepare the way for the subsequent conversion to reach higher energies. In general there is much greater optimism than there was a few years ago that the problems of superconducting r.f. are understood and are being mastered.

Polarization Workshop

A Workshop on Polarized Electron Acceleration and Storage (PEAS) was held at DESY from 22–27 March, one of a series sponsored by the International Committee for Symposia on High Energy Spin Physics of which the Chairman and moving spirit is Alan Krisch from Michigan.

Topics were concentrated around polarized electron and positron beams in electron-positron and electron-proton storage rings. This was very appropriate since DESY, the host Laboratory, has both recent success with polarized beams in PETRA and has the HERA electron-proton project under active study.

Some 45 participants representing about twenty institutes took part, about one-third of them coming from the USA, Canada, Japan and the USSR. Nearly thirty papers were presented, about half of them in plenary sessions, indicating the high level of interest and activity in the field.

After the traditional introductions and welcome by V. Soergel, Director of DESY, and Gus Voss, Chairman of the Organizing Committee, the Workshop took off with a lively review of physics with polarized electron and positron beams by Richard Taylor of SLAC. Describing his reaction to giving this talk as 'rather like an atheist being asked to say grace at dinner', he nevertheless showed that interesting results had been obtained in the past with polarized beams and would no doubt continue to be obtained in the future.

The main subjects were divided into four groups, each under the guidance of a convener. Polarization measurements and results, depolarizers and other related topics were taken care of by Roy Schwitters (Harvard), beam-beam depolarization by Ernest Courant (Brookhaven), single-beam depolarization, resonances and correction procedures by Jean Buon (Orsay) and spin manipulation with rotators and 'Siberian Snakes' by Klaus Steffen (DESY). Each convener gave an introductory review of his field in plenary sessions on the first day, in order to provide starting points for the subsequent working group activities.

In view of the number of papers and discussions, parallel sessions were inevitable, much to the regret of many participants. Although a valiant effort was made by the conveners to minimize the overlap of presentations and discussions, it was not possible to follow all topics in detail. A brief review of progress and plans was therefore given by each convener every morning. The last day opened with detailed summaries by the conveners of the results of their working groups followed by a panel discussion of these results in the closing session.

A primary concern of the Schwitters working group was the problem

Polarization specialists (left to right), Klaus Steffen, Jean Buon and Bryan Montague at the DESY Workshop.

(Photo DESY)

Participants at the recent Polarization Workshop held at DESY.

of measuring the polarization of stored electron and positron beams at high energy. The argon laser polarimeter has proved successful at SPEAR and PETRA and it was conforting to see it confirmed as eminently suitable for the higher energy ranges of LEP and HERA. With a standard 80 W (peak) cavity-dumped laser the polarization in LEP could be measured to 1 per cent in a minute or less. For HERA with 210 bunches the laser would run continuously at 5 W. Bremsstrahlung and synchrotron radiation background should present no problem because of the high energy of the Compton back-scattered photons. For this study Roy Schwitters nominated M. Preger (Frascati) 'Hero of the Workshop' for staying up until four in the morning working out Compton cross-sections with a pocket calculator! Alternative polarimeters were considered but, at least up to LEP energies, the Compton scattering method is preferred.

With all the problems of obtaining polarized beams it may seem strange that depolarizers could be of interest. However, as Ju. Shatunov (Novosibirsk) reminded, the controlled use of an artificially-induced spin resonance has provided high-precision measurements of several particle masses in VEPP-2M. They plan to measure the gyromagnetic anomaly (g-2) of the electron and the positron to about 10^{-8} in VEPP-4 by this means.

What is fascinating for high energy rings is the possibility of adiabatic spin reversal of one of the beams (electrons or positrons) by means of a pulsed depolarizer-like device. The principle has been demonstrated experimentally in VEPP-2M and first estimates indicate that it might be feasible in LEP. Electroweak theory predicts suppression of weak interactions with fully polarized electron-positron beams in the normal (zero-helicity) state; spin reversal of one species should double the weak interaction cross-section. Much more study will, however, be necessary to establish the feasibility of this controlled spin-flipping technique.

Polarized protons in HERA seem feasible but need further physics justification. New ideas are required to make internal polarimeters for protons, since the Compton cross-sections are around a million times smaller than for electrons. Alternative polarization methods for electrons were also discussed.

The depolarization of colliding electron-positron beams by the strong and non-linear forces of the beam-beam interaction has been a subject of much concern since the early experiments on SPEAR. It was therefore encouraging for Courant's working group that a few weeks previously PETRA had sustained polarized beams around the 80 per cent level with no loss of polarization in collision and with a respectable luminosity of 3×10^{30} per cm^2 per s.

An important feature of the PETRA experience is that polarization can be maintained with colliding beams up to levels of current where the beam begins to blow up vertically, after which depolarization sets in progressively with increasing beam current and beam size. This demonstrates experimentally the correlation between spin and orbit behaviour predicted theoretically by A. Kondratenko (Novosibirsk).

It appears likely that some of this depolarizing effect is due to the purely linear part of the interaction causing a 'spin mismatch', and that some degree of correction might be feasible. There was considerable discussion around the possibility of applying 'spin transparency' conditions, proposed by K. Steffen, to the interaction point in order to reduce the linear effect. Non-linear resonances were discussed and although there is little new to report, a better understanding of the theoretical work from Novosibirsk was obtained.

The Buon working group addressed a number of problems connected with ring imperfections and intrinsic properties of storage rings. Most of the depolarizing effects are related to a quantity introduced by the Novosibirsk group which has been the subject of much debate. In recent times it has been called the 'spin chromaticity' or the 'spin dispersion' which do not adequately describe its nature. The Workshop provided the occasion for clarifying definitions and Kondratenko's proposal of 'spin-orbit coupling function' was accepted as precise, if cumbersome, terminology.

Electron storage rings above 10 GeV require special correction schemes for orbit errors and vertical dispersion in order to suppress harmonics near the spin precession frequency. Encouraging progress on both experimental and theoretical fronts has been made. The theory and simulation of the correction procedure, which raised the polarization level in PETRA from 20 to 80 per cent, was described by R. Schmidt (DESY). Proton machines were not forgotten and E. Grorud (Saclay) reported on the correction method at SATURNE which permitted the successive crossing of seven spin resonances (some with complete adiabatic spin reversal) with an overall reduction of polarization from 80 to 74 per cent.

Error-correction procedures are now well advanced and have resulted in a new technical jargon — 'spin matching' to achieve 'spin transparency' as mentioned above. Spin-matching constraints on orbit parameters proposed by A. Chao (SLAC) and K. Yokoya (KEK) have been extended by Steffen and by S. Holmes (Columbia). They are now ten in number (referred to by Chao as 'the ten commandments') but appear to be quite feasible if applied only to the harmonics near the spin frequency. A new proposal by Yokoya applies similar principles to the correction of spin resonances driven by betatron oscillations and shows great promise.

This working group also considered the increased energy spread of the beam at higher energies, which gives rise to synchrotron satellite resonances. More studies are required but at present it appears that special measures may be necessary above 50 to 60 GeV, such as Siberian Snakes or dipole-octupole wigglers to reduce the tails of the energy distribution.

The Steffen working group examined the requirements of spin matching for rotators and Siberian Snakes. Rotators are required to turn the direction of polarization parallel to the beam at the interaction points, in order to provide longitudinal polarization at the detector and to restore it to the original direction on the other side. Siberian Snakes are similar but reverse the direction of the polarization vector; their purpose is to make the spin frequency essentially independent of energy, thus removing many resonance problems.

Both devices introduce substantial vertical bending and require careful spin matching to avoid depolarization effects, especially in the presence of the quantized synchrotron radiation. This seems to be perfectly feasible but imposes extra constraints in the rotator sections.

An interesting proposal by Kondratenko of combining rotators with polarizing wigglers could enhance the overall polarization of a storage ring whilst reducing the space required for the rotator. The practical implications of this will require detailed study.

The overall impression of the Workshop was one of a considerably improved understanding of spin resonance effects and the possibilities for their correction. The vital interest in polarized electrons for electron-positron projects has no doubt had an influence on the increased participation in these studies. For electron-positron storage rings, earlier pessimism on the feasibility of polarized beams at higher energies was no encouragement for their implementation but the recent developments should redress that situation. Some problems remain to be solved and many details have to be worked out but the outlook for polarized electron and positron beams is definitely healthy.

(We are grateful to Bryan Montague for this report.)

Laser-Driven Accelerators

With the latest series of high energy projects (ISABELLE 400 GeV proton-proton storage rings, UNK 5 TeV fixed target proton synchrotron and LEP 50—130 GeV electron-positron storage ring), many people believe that we are seeing the final generation of conventional machines. This is not because the acceleration or beam storage mechanisms involved have reached some technical limit (on the contrary they seem capable of extension to cope with still increasing energies) but because we are running into the limits of what Burt Richter calls 'fiscal feasibility' due to the size of the machines. Construction and operating costs would become extremely difficult to confront.

This realization has provoked concern about appropriate research and development on novel acceleration techniques. A HEPAP sub-committee in the USA, chaired by Maury Tigner, issued a 'call to arms' in 1980 to ensure sufficient attention for such long-range accelerator research even in hard financial times. In Europe, ECFA is taking up the same theme in organizing a Conference in Oxford in September of this year (see page 151).

From the physics side a similar plea has come from Abdus Salam (see 'A message from gauge theories', October issue 1981, page 347) since he was worried that the energy regime for interesting physics is moving beyond what can be experimentally investigated. Salam in particular mentioned the extremely high voltage gradients available in laser beams as one of the possible routes to a new high energy regime. The power densities and strong electric fields in laser beams have led to speculation over many years as to their application in accelerating particles to high energies.

In order to give more direction to this area of research in the USA, a Workshop on 'Laser Acceleration of Particles' was held at Los Alamos from 18—23 February bringing together some sixty physicists and engineers with expertise in the fields of accelerators and of lasers.

Several devices for using laser fields have been proposed and they can be classified in three broad categories — 'far-field' accelerators (such as the principle of inverse free electron lasers), 'media' accelerators (which, for example, use the inverse Cherenkov effect or laser-controlled plasma waves), and 'near-field' accelerators (using a loaded guiding structure such as cavities or gratings). These different approaches come from the fact that a particle cannot be accelerated by the absorption of single photons (because of momentum conservation) and thus some other element has to intervene.

In the 'far-field' type a particle moves in the same direction as a light wave and slightly slower. It experiences a transverse field which is almost cancelled by the magnetic field in the opposite direction. If, however, the particle orbit can be modulated, for example, by static undulator magnets, the magnetic field transforms transverse into longitudinal energy and the particle will be continuously accelerated (or decelerated if in the opposite phase). This is the inverse of the free electron laser mechanism.

This type (and related 'two-wave' accelerators) were discussed at the Workshop and it seemed clear that they are not appropriate for very high energies. They involve substantial deviations from straight-line motion which becomes increasingly difficult at high energies and the rate of acceleration falls. They could, however, cope with energies of a few GeV and handle very high (kiloamp) currents.

The above limitation does not apply in the 'media' type of laser accelerator where accelerating fields are created by polarizing media. An example is the inverse Cherenkov effect where experiments have already been carried out at Stanford (reported by R. Pantell). They operate by having laser light cross a beam of electrons in a gas cell at the Cherenkov angle. Electrical breakdown in the gas is believed to limit the peak accelerating field to several hundred MV/m and accelerators of up to 50 GeV were discussed. Multiple scattering and radiation in the gas may be a problem when aiming for high energies.

Another accelerating mechanism relies on the 'ponderomotive' force produced by laser beams in a plasma (the type of force associated with radiation pressure) producing moving bunches of electrons. The collective electrostatic field of the electrons is then used to accelerate particles. In the 'ponderomotive snowplow' proposed by W. Willis, high energy protons are injected into the electron bunch which is known to travel in a short wave packet of laser light traversing a plasma. T. Tajima and A. Dawson emphasize the acceleration of electrons picked up from the high energy side of the thermal tail in the plasma, and accelerated across the bunch. Computer simulations of these effects were presented by Tajima and D. Sullivan and an experiment using a powerful CO_2 laser was described by C. Joshi, in which acceleration of more than 1 MV was observed in good agreement with the simulations.

A good variation on this scheme was described by Tajima in which the beat waves created by two nearby laser wavelengths are used instead of the short wave packet. The snowplough effect is most efficient when the wavelength of the beats is matched to the wavelength of the plasma waves. Joshi showed results of an experiment in which a carbon dioxide laser was run at two frequencies to create the beat wave and the presence of the plasma wave was verified by Thompson scattering of laser light. Sullivan showed a movie of a simulation of that mechanism in which accelerating gradients of 50 GV/m were developed. The physics of these processes is interesting but it obviously remains to be demonstrated that plasmas can be sufficiently well controlled.

The 'near-field' type of laser accelerator can be typified by acceleration using the longitudinal field associated with evanescent waves near a grating. A simple wave would have accelerating gradients falling towards zero as the velocity approaches that of light but a substantial accelerating field could be retained between two gratings a fraction of a wavelength apart or by a single-grating illuminated by composite laser waves. R. Palmer put forward this latter possibility which might result in accelerating gradients of 1 GeV/m. However the accelerated currents are likely to be small (perhaps only 10^4 particles per bunch) compared to the conventional linac.

The similarity between a grating and a linac was explored. This led to consideration of an optimum wavelength — longer wavelengths allow higher currents but the breakdown fields associated with longer pulse-lengths is lower. M. Tigner worked out that the optimum may lie in the 1 to 10 mm region. Suitable high power lasers have not been developed in this region but this could change with the advent of, for example, the free electron laser.

The working groups urged that the limits on acceleration in gas in grating structures be measured as a function of wavelength and that further experiments on accelerating gradients in plasmas be carried out. The Workshop summary was presented by J. Lawson and the proceedings will appear in about six months.

There are some topics of basic physics concerning the interactions of laser fields with particles, plasmas and materials which clearly need further study and the road to realizing the great potential of laser accelerators is sure to be a hard one. Nevertheless emerging from the Workshop was a recognition of the great potential which exists and the identification of laser-driven accelerators as a specific field for investigation and systematic development. These matters, among others, will be reviewed in the ECFA Conference on novel particle acceleration techniques at Oxford in September.

(We are grateful to John Lawson, Andy Sessler and Bill Willis for providing us with information from which this article is drawn.)

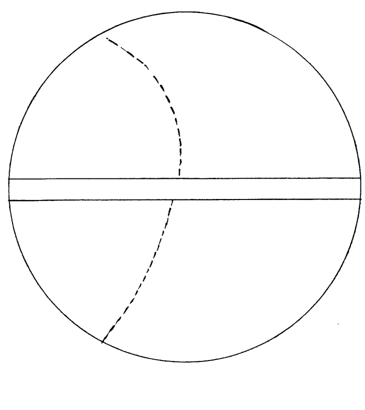
50 years of positrons

This year marks the 50th anniversary of one of the major landmarks of modern physics — the discovery of the positron, the antimatter counterpart of the electron. This provided the first evidence for antimatter, and it was also unprecedented for the existence of a new particle to have been predicted by theory. The positron and the concepts behind it were to radically change our picture of Nature. It led to the rapid advancement of our understanding, culminating some fifteen years later with the formulation of quantum electrodynamics as we now know it.

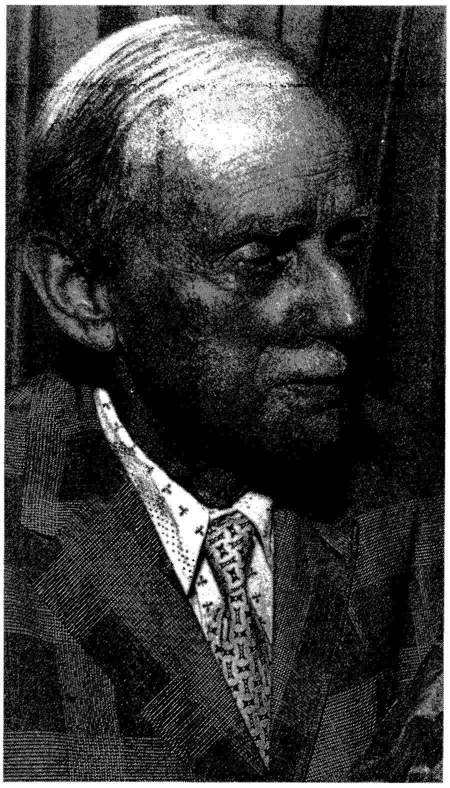
In addition, the past half century has seen positrons develop from a curiosity into one of the major tools — in electron-positron colliders — for today's particle physics research. If the list of proposed new high energy projects is anything to go by, they will continue to be exploited for a long time to come.

(Oddly enough, this year is also the fiftieth anniversary of another major milestone in particle physics — the discovery of the neutron. This we shall be returning to later this year. But it is clear that in view of these two major advances, 1932 could

Sketch of the first positron event, seen by Carl Anderson in 1932 in his cloud chamber exposed to a magnetic field of 15 kilogauss. A 63 MeV cosmic ray positron entered the chamber from below, lost energy in the central lead plate, and emerged again in the top half of the chamber. The difference in track curvature between the two halves of the chamber showed that the particle was definitely moving upwards.



Paul Dirac, whose theory of the electron set the scene for the discovery of the positron 50 years ago.



well be cited as the dawn of particle physics.)

It was on 2 August 1932 that Carl Anderson, working at California Institute of Technology, saw a cosmic ray event in his detector that he dared to propose as being due to a positively charged electron. In fact this was not the first time that anyone had seen such effects — tantalizing hints of positive electrons had been glimpsed up to seven years before by Skobeltzyn, Rochester, Feather, Meitner, the Joliot-Curies, Millikan and others, including Anderson himself. Although positive electron tracks had probably been encountered, nobody had ever identified one as such.

On the theoretical side, the positron story unfolded largely through the genius of Paul Dirac. Not content with his beautiful new formulation of non-relativistic quantum mechanics, Dirac had begun to grapple with the challenge of electrodynamics and special relativity. In 1928 he published the electron equation which now bears his name.

As well as reproducing all that had gone before, the new equation had something else. It appeared to say that electrons could have negative, as well as positive kinetic energy. Dirac argued that this 'sea' of negative energy electrons is normally full except for occasional unoccupied states, or 'holes'. In an electromagnetic field, such a hole would act as though it has opposite electric charge to a normal electron. At first, Dirac proposed that these positive charges were the protons of atomic nuclei, much heavier than the electrons. However this appeared to bother him, as the symmetry of the theory suggested strongly that the two solutions of the equation should have the same mass.

When the proton dropped out of the running, Dirac in 1931 boldly postulated the existence of an as yet unseen 'antielectron'. Because of its affinity for ordinary electrons, this would be difficult to find in ordinary matter, but could perhaps be produced in interactions involving hard gamma rays. The stage was set for Anderson's discovery.

For some time Anderson thought that he had been seeing positive electrons, but had no proof. The vital ingredient in his new experiment was a lead plate, slightly more than a centimetre thick, mounted across his cloud chamber. This was subjected to a magnetic field of 15 kilogauss. Cosmic ray particles passing through the metal plate would lose energy, leaving the plate in a tighter curve than they went in. This gave the direction of motion of a charged particle in the magnetic field. Previously it had not been clear whether electron-type tracks were due to an ordinary electron going one way or a positive electron moving in the reverse direction.

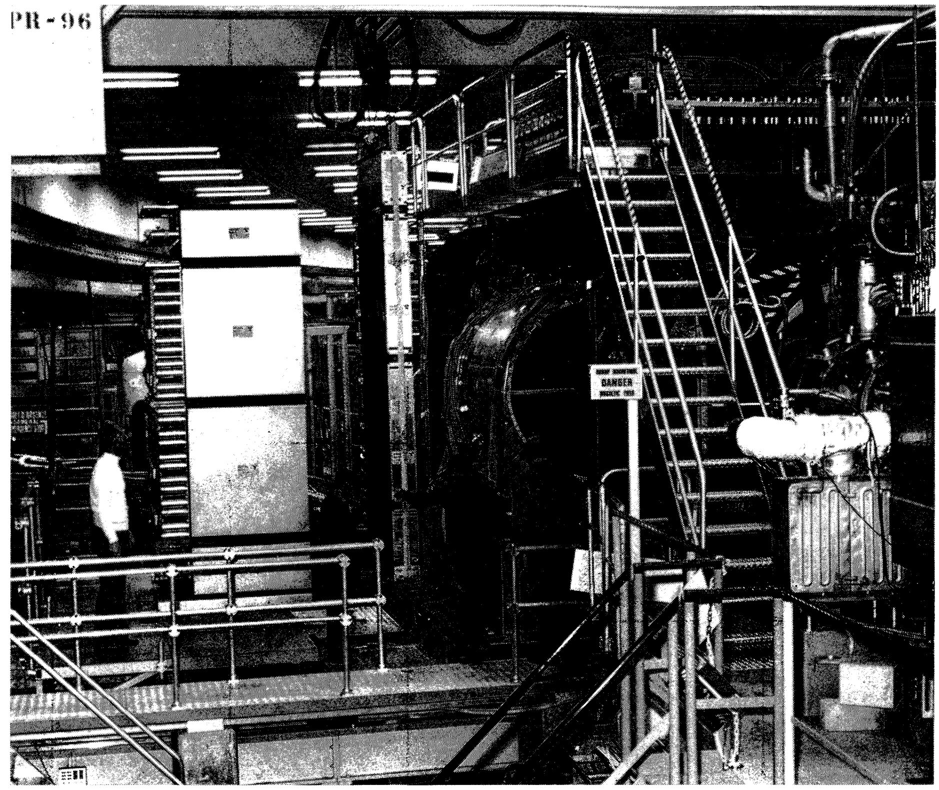
After painstaking work, Anderson found an event which he proposed as a 'positron' candidate (the name was Anderson's own contraction for 'positive electron'). This was a bold move since the positively charged track involved was due to a stray cosmic particle which in fact had entered the chamber from below!

This was indeed a courageous step to take at the time, as although the particle had been predicted by Dirac, this theoretical work was not yet universally known and many contemporary authorities did not subscribe to these ideas anyway.

Soon Anderson had obtained many more positron tracks, and supporting evidence came from P.M.S. Blackett and G.P. Occhialini working with their newly-developed Geiger counter-triggered cloud chamber, who showed that the positron was indeed the Dirac antielectron.

Antimatter had been discovered, but physics had to wait until 1955, with the sighting of the antiproton (also predicted by Dirac) at the Berkeley Bevatron, for a glimpse of another antiparticle.

Around the Laboratories



An unusual 'exploded' view of the detectors at Intersection 8 of the CERN Intersecting Storage Rings. On the right, the superconducting magnets of the 'low-beta' insertion are just visible. On the left, a wall of uranium-scintillator hadron calorimeter stands ready to be moved into position. Another wall of uranium calorimeter is seen near the roof. Centre, half of the inner cylinder of drift chambers has been drawn back.

(Photo CERN 306.1.82)

CERN
All routes to Intersection 8

The high luminosities and elevated collision energies available at the CERN Intersecting Storage Rings (ISR) provide good conditions for studying the behaviour of the rare high transverse momentum reactions in which the quark constituents of colliding hadrons come into close contact.

While higher collision energies are now available from the SPS proton antiproton collider (270 GeV on 270 GeV compared with the ISR's 31 GeV on 31 GeV), the luminosities are as yet low (some 10^{27} cm^{-2} s^{-1}) by ISR standards (in the 10^{31} range). This means that the ISR still provides a good hunting ground for rare events.

With this in mind, a big physics programme is under way at ISR Intersection 8, which is fitted with a unique superconducting 'low-beta' insertion to squeeze the beams and achieve luminosities several times higher than those available in other intersections (see March 1981 issue, page 59).

At the heart of the new detectors is the 300 ton Axial Field Magnet (AFM) of the Brookhaven / Cambridge / CERN / Copenhagen / Lund / Queen Mary College / Pennsylvania / Rutherford / Tel-Aviv group, with an inner cylindrical arrangement of drift chambers supplemented by uranium-scintillator hadron calorimetry and a large array of Cherenkov counters (aerogel, high pressure and low pressure freon).

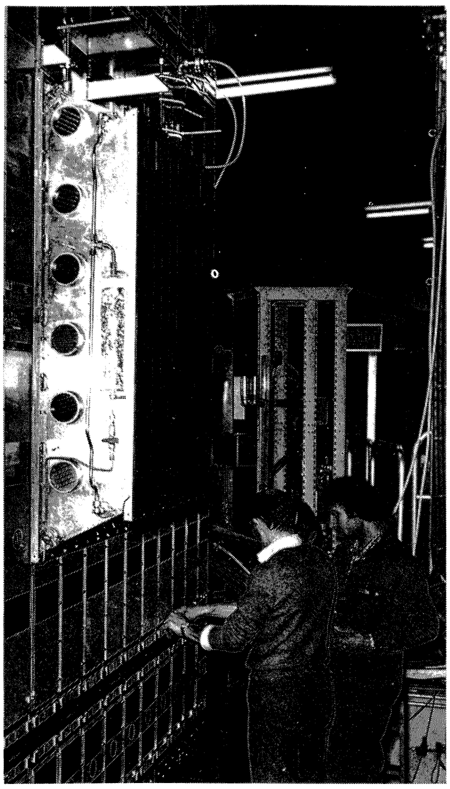
The previous tenant was a liquid argon calorimeter set-up (Athens / Brookhaven / CERN) which blazed a trail for this kind of detector and carried out some commendable physics, including the first systematic study of the single photons arising from quark-gluon interactions. For a while the liquid argon and AFM configurations took data together, but now the liquid argon units have been removed, and their place taken by an additional uranium-scintillator hadron calorimeter wall.

In the current ISR run, jets of particles can be intercepted on three sides in the uranium and the recoil particles picked up in the Cherenkov counters on the fourth side. In a few months, the Cherenkov array will also be removed, making way for a fourth uranium wall. This will provide good conditions for triggering on high total transverse energy to scan for signs of jet production, which seems to be fuzzy at lower transverse energies.

New drift chambers have been installed in the very forward regions, beyond the superconducting dipoles, to measure high momentum protons associated with central particles. They will be used to search for new hadrons such as bound gluon states ('glueballs').

With the pioneer liquid argon calorimeters now gone, the spirit of single photon physics carries on at Intersection 8 with a new study by an Athens / Bonn / Brookhaven / CERN / Moscow / Novosibirsk group using two arrays of 600 sodium iodide blocks with vacuum photodiode readout mounted inside the main uranium calorimeter. Data samples have been taken with the first 'crystal wall' mounted inside the newest slab of uranium calorimeter. Another array will be installed later this year with the fourth wall of uranium.

More information on single photon production comes from a hexagonal uranium-scintillator insertion mounted inside the forward cone of the magnet, 1.7 m away from the intersection point along the beam.

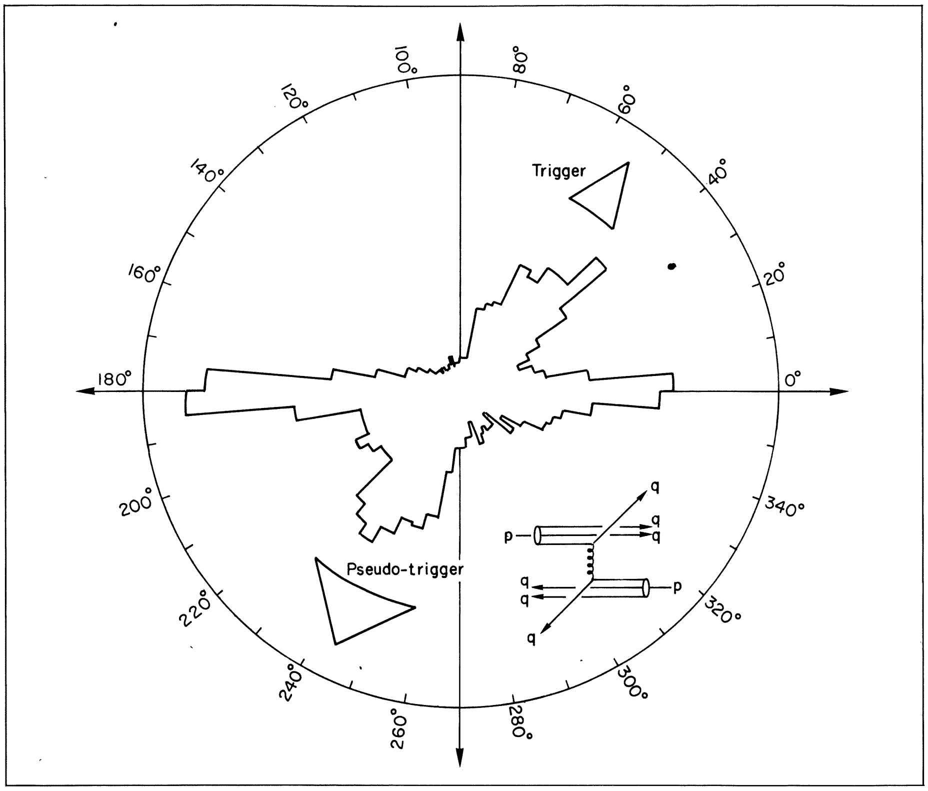


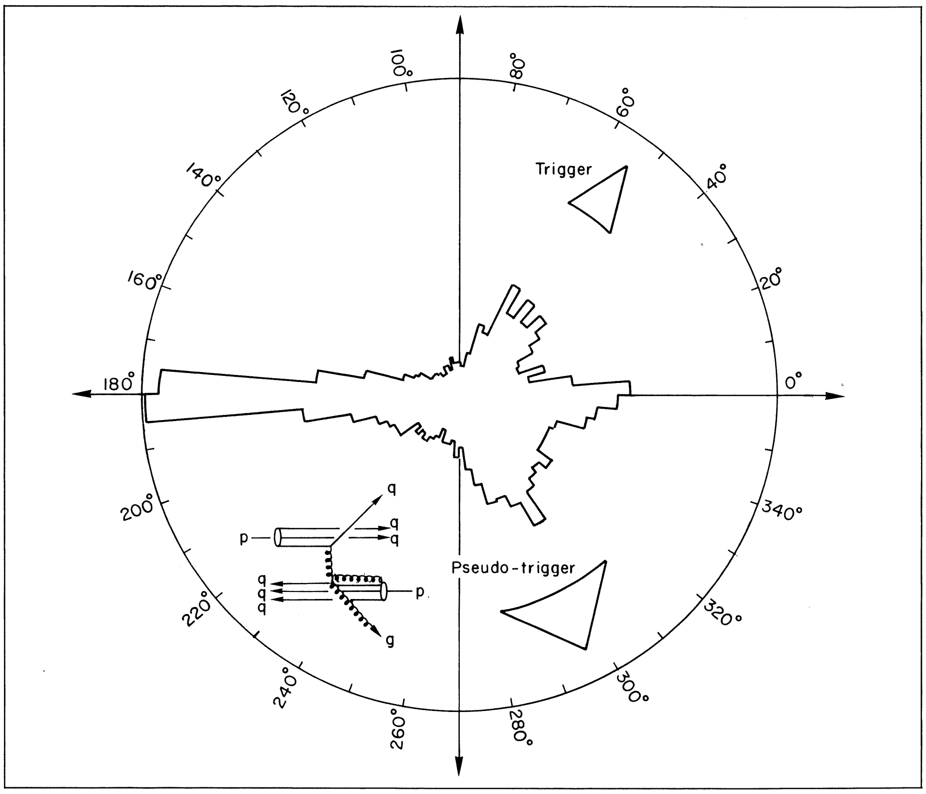
One of the new arrays of sodium iodide blocks for measurements on single photons, mounted on one of the inside walls of the uranium hadron calorimeter of the experiment at Intersection 8 of the CERN Intersecting Storage Rings.

(Photo CERN 449.2.82)

This versatile range of detectors is efficiently exploited by employing CERN-designed microprogrammable processors for complex trigger decisions and event filtering. Two 'ESOP' processors reconstruct tracks on-line and select particles satisfying various kinematic requirements, or matching localized energy deposited in the calorimeter. In parallel, a very fast analogue computer analyses the calorimeter signals and is programmed to select events based on particle type and on the level and topology of the energy deposited. Different parallel triggers, each with a typical selectivity at the 10^6 level, provide data for several effectively independent studies.

This impressive array of apparatus could soon go on to produce some interesting new physics results at the ISR, now into its second decade of operation.





'Classical' jet patterns seen at the CERN Intersecting Storage Rings using high transverse momentum single particle triggers.

Classic jets

Searches for particle jets continue. Experiments are looking for well defined sprays of secondary particles by collecting all the transverse momentum of the particles produced in high energy collisions (see previous story).

Meanwhile 'classical' jet studies at the CERN Intersecting Storage Rings continue to look at the momentum flow in selected rare events in which single large transverse momentum particles act as triggers. Although such events should represent only a small fraction of total jet production, they have a particularly clean signature and can be used to study aspects of jet physics.

These single particle triggers collected at the ISR appear to drive a well defined momentum flow. A typical result is shown here (top diagram) in an event sample from the Annecy / CERN / Collège de France / Dortmund / Heidelberg / Warsaw group using the Split Field Magnet detector. It comes from about a thousand single particle triggers (with transverse momentum greater than 4 GeV on the trigger side together with a recoiling particle greater than 2 GeV on the 'away' side). The trigger particles themselves have been removed, and the result clearly shows the clustering of the accompanying particles. These effects are interpreted as being due to gluons exchanged between pairs of quarks in the colliding protons, and the subsequent 'hadronization' of the deflected quarks.

The bottom figure shows a similar sample, this time with non-opposite single particle triggers (momentum above 2 GeV) and accompanying particles which together appear to carry no 'flavour' (charge, strangeness, etc.). This jet pattern is thought to arise from a different class of interaction in which a gluon is exchanged between a quark of one proton and a gluon accompanying the other proton. One jet is thus due to the hadronization of a quark and the other to the hadronization of a gluon. Such interactions involve the celebrated 'three gluon vertex' in which three field particles meet at a single space-time point. Such interactions are thought to be very characteristic of the gauge theory describing the underlying quark/gluon interactions.

More detailed results on the momentum and quantum number structure of these jets and comparison with theoretical calculations are expected soon.

KEK
First photons from factory

The 'Photon Factory' (synchrotron radiation research facility) being built at the KEK Laboratory in Japan had a successful first series of tests in February and March.

The Factory consists of a 2.5 GeV electron linac (of total length 450 m) and a storage ring (50 m × 70 m oval). Construction started in April 1978 and the first quarter of the linac was completed in July 1981 giving 500 MeV beam in the first test. Injection into the storage ring started on 8 February this year and the linac was able to supply a 2.2 GeV beam of 55 mA two days later.

The first turn was observed on 18 February and more than 10 turns were obtained on 27 February. More stable coasting beam with a lifetime of 120 μs was obtained without r.f. on 5 March and r.f. acceleration was applied on the same day. Beam accumulation reached 5 mA at 1.57 GeV on 9 March and 6.2 mA at 2.5 GeV two days later.

Maximum beam accumulation was tried on 18 March and more than 100 mA at 1.68 GeV was obtained, when the increase per pulse of injected beam was 20 mA/pulse. At present, the vacuum of the storage ring is about 10^{-8} torr without beam and 10^{-6} with beam. This is mainly due to the fact that baking of the vacuum system has not been done and cooling water and distributed pumps are still off. Four beamlines are already provided for experiments, which will start soon.

ORSAY
Prototype LEP pre-injector

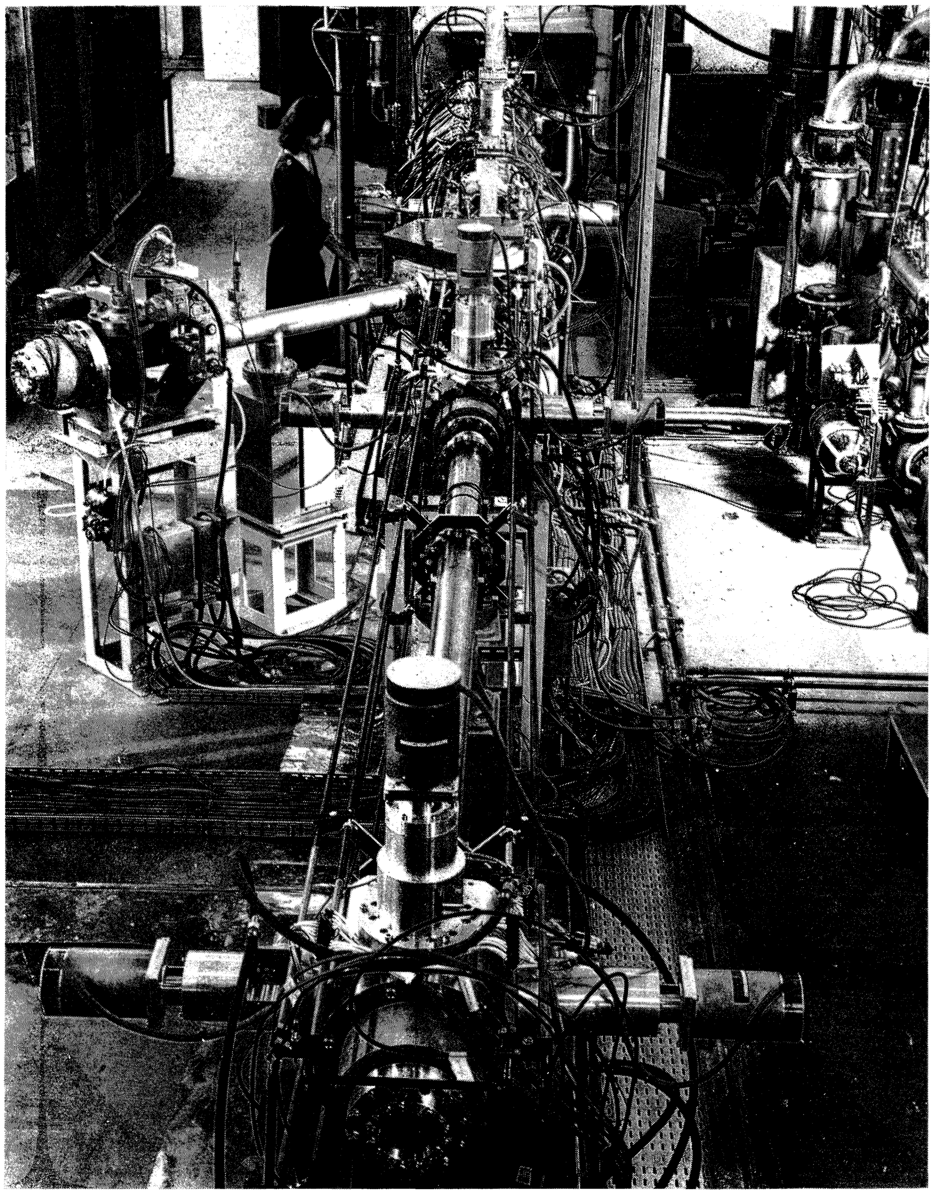
From the very beginning of the LEP electron-positron collider project, efficient performance of the electron gun and the buncher which form the front-end of the LEP pre-injector has always been regarded as a priority. The two major reasons for this are that the relatively short stored-beam lifetimes of several hours necessitate short LEP filling time (of the order of 20 minutes) and that allowance must be made for the complexity of the LEP injection system which will tend to reduce the overall efficiency of particle transmission.

Since the positron beam is produced from the impact of the electrons on the converter target, its intensity is directly proportional to the intensity of the electron beam, but it is also affected by the quality of the bunching. A high gun current and an efficient buncher are therefore essential to obtain an electron beam of the required density and intensity. Another factor is the emittance of the electron beam which determines the size of the spot on the converter.

Computer simulation of the dynamics of an intense beam from the gun cathode to its exit from the buncher is not easy, and the results should, in any case, be treated with a degree of caution. In the absence of any reliable experimental results, it was decided to complement the considerable amount of work being undertaken in this field, notably at Orsay, by constructing an experimental linac front-end compatible with the LEP Project, in Phase 1 at least. In addition, it would be an invaluable early source of information on machine performance, permitting improvements to be planned for a later phase of the project. The experimental equipment would therefore require a complete set of monitoring devices to precisely assess the initial conditions of electron acceleration.

The pre-injector research programme was included in the original Orsay / CERN collaboration agreement which was drawn up in May 1979. After tendering, the contract for the design and construction of the 100 kV 20 A triode gun and the 20 to 30 MeV buncher was awarded to the Compagnie Générale de Radiologie (CGR), while Orsay takes responsibility for the r.f. power source, for the monitoring equipment, for on-site installation of the experimental assembly and for the measurements. Installation has now been completed and acceptance tests for the various parts of the equipment are being carried out.

The gun cathode is made of porous tungsten with incorporated oxides and is heated indirectly, while the grid is made of molybdenum. The cathode, the grid and their associated circuits (the filament heating circuit and the modulator respectively) are operated at a constant maximum voltage of 100 kV. Except when the short current pulses are being applied, the grid is maintained at a constant potential in relation to the cathode, which has the effect of blocking cathode emission. The average flow of current from the cathode and of the pulses crossing the anode aperture can be measured using a cylindrical electrode.



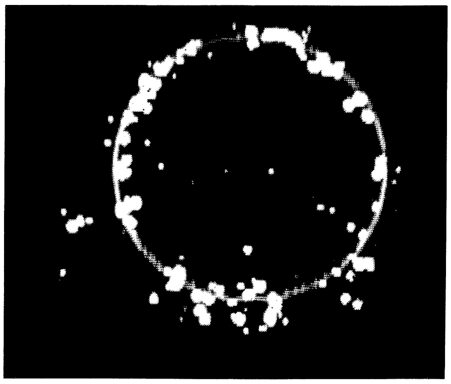
The prototype LEP pre-injector now being tested at Orsay.

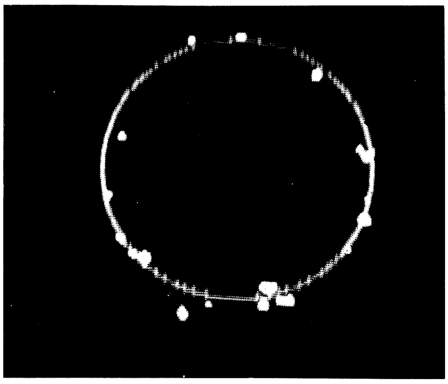
(Photo Orsay)

The specification for the gun and the modulator stipulated that the current pulses should have widths variable from 3 to 18 nanoseconds using 4 shapers (3 to 6 ns, 6 to 10 ns, 10 to 14 ns and 14 to 18 ns). For 80 kV, the maximum peak current guaranteed by the manufacturer is 10 A, as compared to the current predicted for 90 to 100 kV of the order of 20 A. To date, however, peak currents at the anode exit of 14.5, 17 and 20 A have been obtained for 80, 90 and 100 kV respectively. One of the major problems so far encountered has been the vacuum conditioning of the gun.

The CGR MeV type buncher contains the following components: a pre-bunching assembly consisting of

Computer displays from an optical readout Cherenkov ring imaging detector developed for a Fermilab experiment, showing the rings produced by a single particle (right) and by ten events.





a thin cavity with a constant field of 2.6 MV/m followed by a drift space, and a periodic structure operating in stationary waves in 2 π/3 mode and consisting of cavities whose height is proportional to the average velocity of the bunches. One in each group of three cells has a zero field strength and does not contribute to the acceleration process. Given that the minimum cell height must be compatible with the correct r.f. frequency, these cells have been reduced to their simplest form so as to keep the bunching section as short as possible. Solenoids located around the cavity assembly provide magnetic focusing of 2.5 kG.

During preliminary tests, a short pulse of 15 A at the buncher exit was measured for a pulse of 20 A at the gun exit. For a transmitted beam of 8 A, the phase extension measured at mid-height was 12°, a value which agrees relatively closely with the simulated results where the range was estimated to be between 10° and 20° depending upon operating conditions.

Once preliminary tests have been completed, it is hoped that the new equipment will go into routine service as a vital source of information on pre-injection for the LEP Project. But in view of the 24 MeV already obtained, it can be said that the first steps towards LEP energies have already been achieved!

FERMILAB
Striking it RICH

The Ring Imaging Cherenkov (RICH) technique is rapidly gaining ground (see March issue, page 49). Another example of its application is ORCID — Optical Readout Cherenkov Imaging Detector — which has been tested in the Meson Area at Fermilab.

This detector, developed by Barry Robinson at the University of Pennsylvania, uses two spherical mirrors to focus and reduce Cherenkov light produced in 1 m of heavy gas at atmospheric pressure to sharp rings whose radius depends on the Cherenkov angle and whose position depends on the angle of the particle emitting the light. Thus, light from several secondary particles in an interaction can be associated with the particles emitting it with little ambiguity.

The rings are detected with a 40 mm diameter micro-channel plate image intensifier. Further intensification of the image is done by an 18 mm image intensifier. Finally, the intensified spot of light from each photoelectron produced at the first image intensifier falls on a photoelectric array. Each of the 80 000 useful sites on the device is read out and discriminated.

Tests so far have shown an average of about 10 photoelectrons per particle with a dispersion of about 5 per cent of the 47 mr limiting Cherenkov angle. Since each photoelectron represents an essentially independent measurement of the Cherenkov angle, this angle is known to less than 1 mr. This resolution should allow pion/kaon separation between the pion Cherenkov counter threshold at this index of refraction, about 4 GeV, and where kaons approach the limiting angle, at about 35 GeV.

Further tests and calibration are continuing. It is expected that the detector will be available for a major part of an experiment to study high transverse momentum hadronic interactions, carried out by an Argonne / Fermilab / Lehigh / Pennsylvania / Rice / Wisconsin group.

STANFORD
Five times X

As well as delving into finance and funding, SLAC Director Pief Panofsky in his traditional annual 'State of SLAC' address explained how this year is a kind of multiple anniversary for the Laboratory.

'We are planning for what I like to call the "Five times X" anniversary celebration on 14-15 August. Many of the events associated with linear electron accelerator history at Stanford and at SLAC occurred in multiples of five-year intervals. For example the first significant date in this history is 1947 (35 years ago, X = 7), when the first electron beam ever accelerated by a linear accelerator was produced under the inspired leadership of Bill Hansen. This was the original Mark I accelerator, and its first successful operation resulted in perhaps the briefest Status Report ever submitted to a government sponsoring agency (the Office of Naval Research): the entire content of the report was "We have accelerated electrons."

There followed the development of the Mark II and Mark III accelerators at what are now the Hansen Laboratories of Physics on the Stanford campus, and the success of these machines led to tentative planning for a Very Big Machine of this kind. In April 1957 (25 years ago, X = 5), this resulted in the submission to several federal government agencies of a "Proposal for a Two-Mile Electron Accelerator". The machine was known locally as "Project M", or "The Monster", and the proposal was the first formal step taken that eventually led to the creation of SLAC.

Five years later, in April 1962 (20 years ago, X = 4), a contract for the construction of SLAC was signed between Stanford University and what was then the Atomic Energy Commission. This was followed a few months later by the formal ground-breaking ceremonies on the present SLAC site.

The SLAC linac achieved its design energy of 20 GeV in January 1967 (15 years ago, X = 3). First full operation of the linac, with a beam through the full two miles, had been achieved during the latter part of 1966. Shortly afterwards the first important physics results began to come out of the early SLAC experimental programme.

1972 was also a red-letter year in SLAC's history, for this was the year that the SPEAR storage ring first began operating. That was 10 years ago (X = 2). It is worth noting that many particle physicists consider SPEAR to be the most successful single physics tool that has ever been built. (I tend to agree!)

So 1982 is indeed a multiple anniversary of all these events that have made history in the annals of particle physics. If the SLC project is authorized for construction in Fiscal Year 1984 as we now hope, then it may well begin operating in 1986. Perhaps its first major discovery will occur in 1987, so that our interval of five years between great events can be maintained!'

Aerial view of the SLAC site, perhaps soon to look even more complicated if the proposed linear collider project (SLC) is given the go-ahead.

(Photo SLAC)

People and things

Spanish Minister of Industry and Energy Ignacio Bayon Marine (left) was among the party of Spanish officials which visited CERN earlier this year and informed CERN Director General Herwig Schopper (right) that Spain once more wishes to become a CERN Member State. Spain was a member of CERN from 1961 to 1968.

(Photo CERN 289.2.82)

On people

Sharing the prestigious Wolf Prize for Physics are Freeman Dyson, Gerard 't Hooft and Viktor Weisskopf, an illustrious trio whose work spans three generations of modern physical theory, and quantum field theory in particular. Together their contributions range from Weisskopf's early activity in the 1930s, through Dyson's major role in the formulation of modern quantum electrodynamics, to 't Hooft's key developments which led to the revival of field theory in our current understanding of particle behaviour. The prize was presented at the Israeli Knesset in March.

Fermilab Director Leon Lederman has been chosen by the American Academy of Achievement as a 'Giant of Accomplishment' from the US' great fields of endeavour and will receive the Academy's 'Golden Plate Award' during the 21st annual Salute to Excellence weekend to be held in New Orleans from 24—26 June.

The Academy is a non-profit organization dedicated to the inspiration of youth through annual tributes to outstanding achievements in science, the arts, commerce, sport, entertainment and public service. Previous recipients of the Golden Plate Award include writer Isaac Asimov, gene-splicing pioneer Herbert Boyer, Sheldon Glashow, Linus Pauling, Jonas Salk, Glenn Seaborg, Edward Teller and Sam Ting from the field of science, together with Olivia de Havilland, Clint Eastwood, Ray Charles, Henry Fonda, Helen Hayes and James Stewart from the world of entertainment, and many other celebrities.

Meetings

The 1982 Summer Workshop on Proton Decay Experiments will be held from 7—11 June at Argonne National Laboratory. Its purpose is to bring together experimenters and theorists with an active interest in the next generation of proton decay experiments. Further information from David Ayres, High Energy Physics Division, Building 362, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439, USA.

A Workshop will be held at Los Alamos from 19—22 July to discuss the LAMPF II project for a rapid cycling 16 GeV synchrotron providing 10^{13} protons per pulse. It would provide a wide range of secondary beams and would cover a wide physics programme. The goal of the Workshop is to discuss both the accelerator and the physics programme to prepare the way for a formal proposal later this year. Those interested in attending should contact Alice Horpedahl, Mail Stop H831, Los Alamos National Laboratory, Los Alamos, New Mexico 87545 USA.

The challenge of attaining ultra high energies

This is the title of a meeting to review limitations and possibilities in particle acceleration to ultra high energies, organized jointly by ECFA and the Rutherford Laboratory. It will be held at New College, Oxford, UK, from 27–30 September.

Existing accelerator techniques are approaching limits set by size and cost. The meeting will examine these limits and look for other approaches offering the promise of

The CERN Auditorium was packed on 24—25 March to hear first presentations of candidate experiments for the LEP electron-positron collider.

(Photo CERN 327.3.82)

Günter Wolf of DESY, Chairman of the CERN LEP Experiments Committee.

(Photo DESY)

attaining energies far beyond the present horizon.

The topics for discussion will include the use of high electric fields generated in plasmas, external fields in short wave r.f. linacs, and laser illuminated gratings.

Speakers will include Abdus Salam, John Lawson, Gus Voss, Andy Sessler, Maury Tigner, Claudio Pellegrini and James Bjorken. The aim is to interest people in the challenge of overcoming the formidable technological barriers between energies attainable with present acceleration methods and the vast unexplored territory towards 100 TeV.

Attendance is by invitation, as numbers are limited. Applications and requests for further information should be sent (by 25 June) to Ian Corbett, Rutherford Appleton Laboratory, Chilton, Didcot, OX11 OQX, UK.

Wynn Evans

The death of Wynn Evans and his wife Kathleen in a car accident on 13 March has shocked his many friends. His research activities started with cosmic ray work in the late 1940s and over the years he made many significant contributions to cloud chamber and bubble chamber techniques. Indeed his great strength lay in the technical aspects of particle physics and his ability to see how to construct apparatus that could be both elegant and reliable. When the 28 GeV Proton Synchrotron started at CERN he was responsible for the construction and installation of the 1.5 metre British hydrogen bubble chamber. For many years he ran the Film Analysis group at Liverpool and was recently involved in the preparations for holographic systems. He was also an outstanding teacher. He will be sorely missed by his colleagues.

Touschek legacy

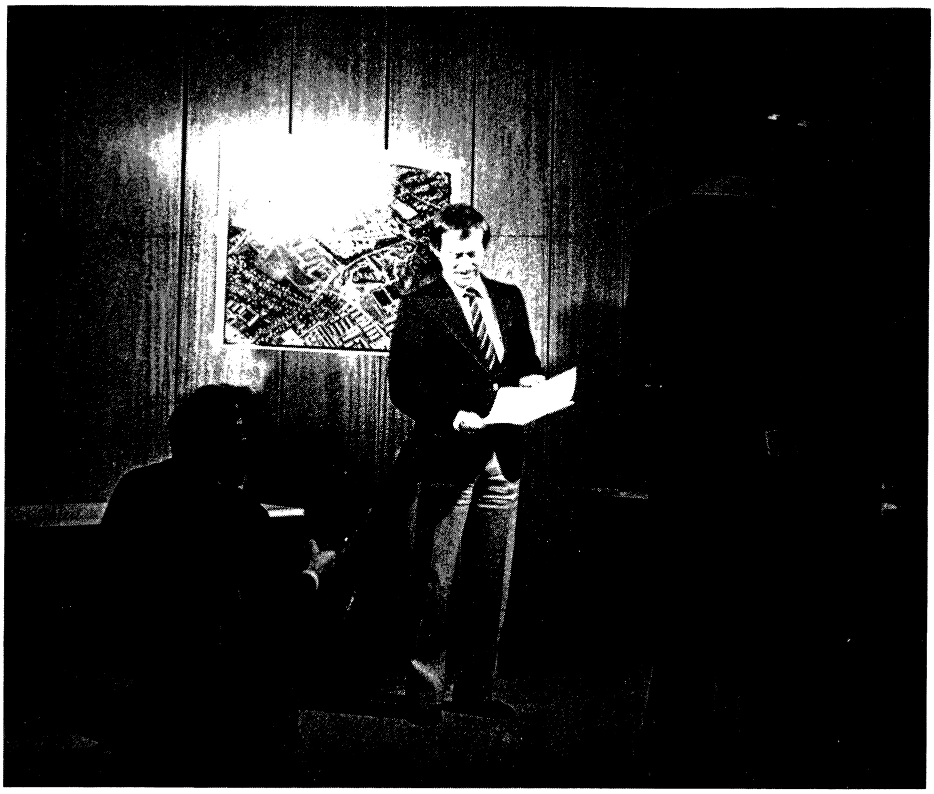
A moving tribute to the life and work of the late Bruno Touschek has been prepared by Edoardo Amaldi and published as a CERN 'Yellow Report' entitled 'The Bruno Touschek Legacy' (number CERN 81—19). It includes an account of his pioneering work in the early 1960s on electron-positron storage rings which led to the construction of the first operating ring, ADA, at Frascati.

TRISTAN and ISOLDE

In our story on the first operation at Brookhaven's High Flux Beam Reactor of the TRISTAN on-line isotope separator (December 1981

The Senate of the City of Hamburg recently presented the Hamburg Parliament with a development plan for the Bahrenfeld region which included the tunnel for the proposed HERA electron-proton collider. North German TV took the opportunity to interview Wolfram Schött of the DESY Directorate.

(Photo DESY)



issue, page 450), how silly of us to overlook that TRISTAN is the natural partner to any ISOLDE. According to the legend of chivalry, Tristan, a prince of ancient Britain, became involved in a tragic romance with the Irish princess Iseult. Through the ages, the saga has been the inspiration for numerous poems, and is now of course immortalized in Wagner's music which uses the more Germanic name, Isolde. In addition, the Brookhaven TRISTAN (a dubious acronym for Terrific Reactor Irradiation System To Analyse Nuclei) first went into operation at a reactor at Ames Laboratory, Iowa, way back in 1966, just before the commissioning of the ISOLDE on-line isotope separator at the CERN 600 MeV synchro-cyclotron.

Theoretician P. Fayet of Paris explaining the implications of supersymmetries at the recent German Physical Society meeting at Karlsruhe. Behind him is Hans Joos of DESY. The meeting also heard a report on the measurements of electroweak asymmetries at the PETRA electron-positron ring at DESY (see page 135).

(Photo E. & P. Hamburg)

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SCIENCE AND ENGINEERING RESEARCH COUNCIL

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High Energy Experimental Physicists

There are vacancies for Research Associates to work with experimental groups in high energy physics. Groups from the Rutherford Appleton Laboratory are working on experiments at CERN, DESY and SLAC.

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Competition No. 320-022

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Please reply in writing, outlining qualifications and experience to:

TRIUMF Personnel (Competition No. 320)
c/o Employee Relations Department
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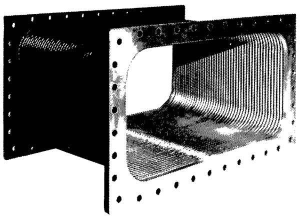

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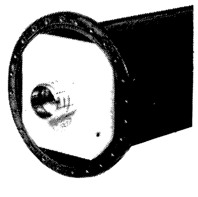

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Professor D.H. Perkins, FRS
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Keble Road
Oxford OX1 3RH
United Kingdom

by Monday 17 May 1982. Applicants should ask referees to write direct to the above address.

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The successful applicant will join the group responsible for the design and development of facility control and experimental data acquisition systems at TRIUMF, and accelerator based nuclear research facility operated as a joint venture by the above universities. The applicant should be accredited or be capable of accreditation as a professional engineer in British Columbia. This is a senior position carrying an initial annual salary in the $35,000 to $40,000 range, depending upon education and experience. Applications will be accepted until May 30, 1982.

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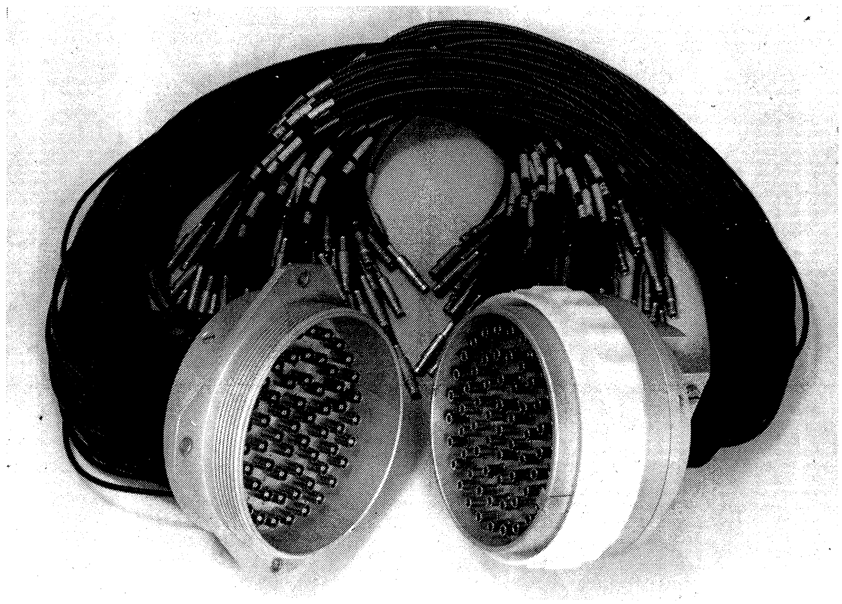

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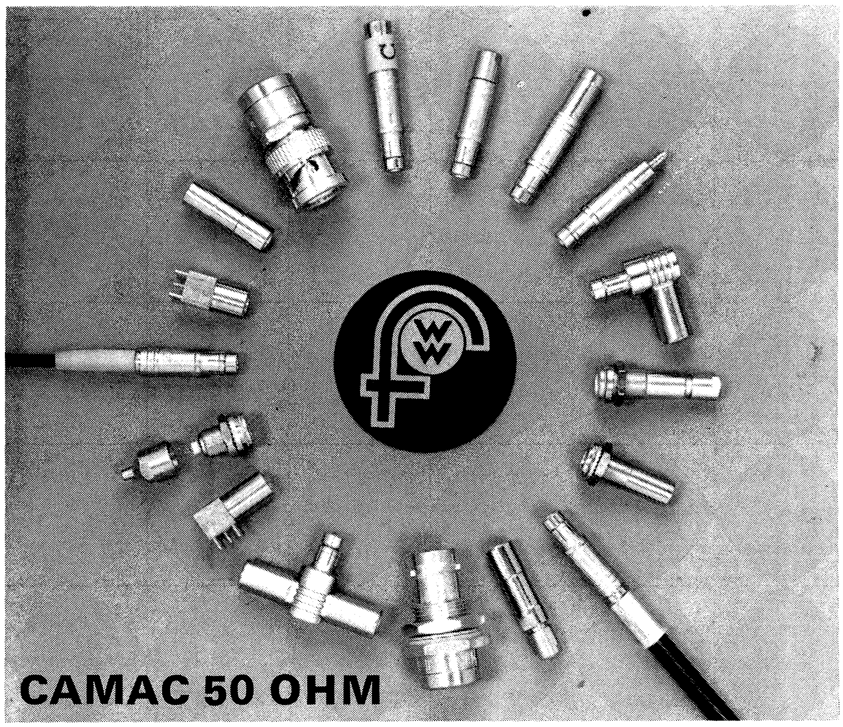

FISCHER connectors with self-locking can now be supplied in 8 different sizes and come in a very wide range:
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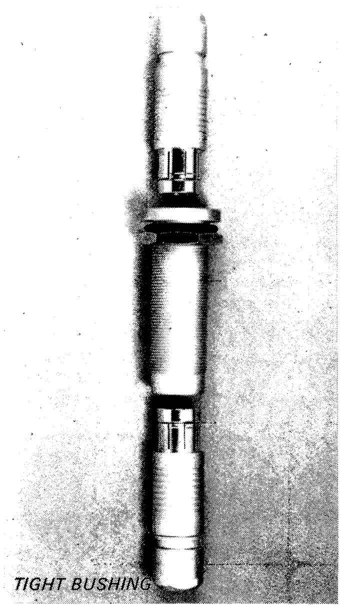
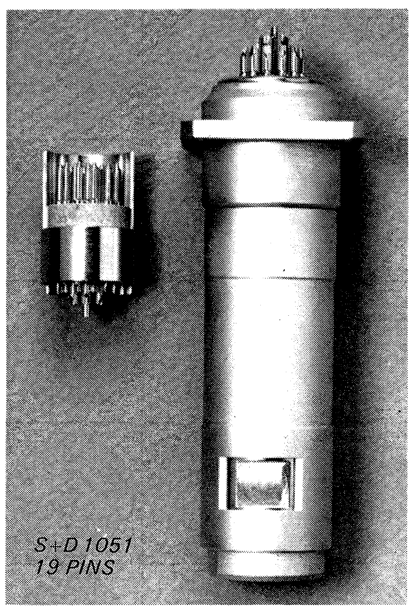


Residual leakage:
$< 10^{-9}$ m bar. l. sec.$^{-1}$



Connectors with CERAMIC insulating material resistant to radiation and to high temperatures

A "SUPERKLYSTRON" DELIVERING OVER 1 MEGAWATT CW NEAR 350 MHz

For CERN's Large Electron-Positron (LEP) accelerator project, sources of very high RF power operating at frequencies near 350 GHz are required, and they must be capable of continuous wave (CW) operation. For this task, the leading candidate is the klystron, because of its capability for generating high levels of output power at microwave frequencies, its high efficiency and large gain, and a structure allowing effective cooling to safely dissipate large amounts of residual energy, when necessary.

As one of the world's acknowledged leaders in klystron design, development and manufacturing, THOMSON-CSF's Electron Tube Division was in an excellent position to develop the one-megawatt tubes necessary for the LEP. Nevertheless, a number of formidable technological problems had to be overcome in developing a klystron of this size and with the desired performances.

One of the major considerations was a capability for tube operation in the horizontal position, inside an underground tunnel of relatively small diameter. Because internal alignment of the different stacked tube parts must be highly precise, it is essential to ensure structural rigidity when the klystron is rotated to the horizontal for transportation and for operation, despite considerable dilation in the latter case. This problem was solved at THOMSON-CSF by the design of a special support structure, mated to the tube.

In addition, an entirely new facility was built to manufacture the tube and to be able to test finished models under realistic operating conditions, including a double-vacuum oven six meters high and two meters in diameter and a 120 kV/20 A power supply.

Efficiency

Over the past several years, THOMSON-CSF engineers have written a number of large-signal computer programs for klystron analysis and design, in order to determine the values of the different parameters that would yield the highest dc-to-RF electrical efficiency. It has been possible to show and amply demonstrate that the lower the perveance (cathode current divided by the 3/2 power of the cathode voltage) the higher the efficiency, and that the number, position and resonant frequency of the different cavities are all of extreme importance. With a perveance of 0.6 to 0.7 × $10^{-6}A.V^{3/2}$, an operational efficiency of 65 to 70 % should be obtainable.

RF Output Window

The output window is in fact the most critical element of a tube at such power levels. Although the dielectric losses are never large, the temperature gradients can become uncomfortably strong. For example, an externally cooled circular Al_2O_3 window on the 1 MW klystron would exhibit a temperature difference between the center and the edge of nearly 100 °C. To overcome this problem, a special water cooling circuit has been designed for the THOMSON-CSF tube, identified as the TH 2089.

The RF output window must also be protected against possible multipactoring.

A special transition in the TH 2089 enables matching the coaxial line from the final resonant cavity to WR 2300 rectangular waveguide, to which the accelerating structures will be connected.

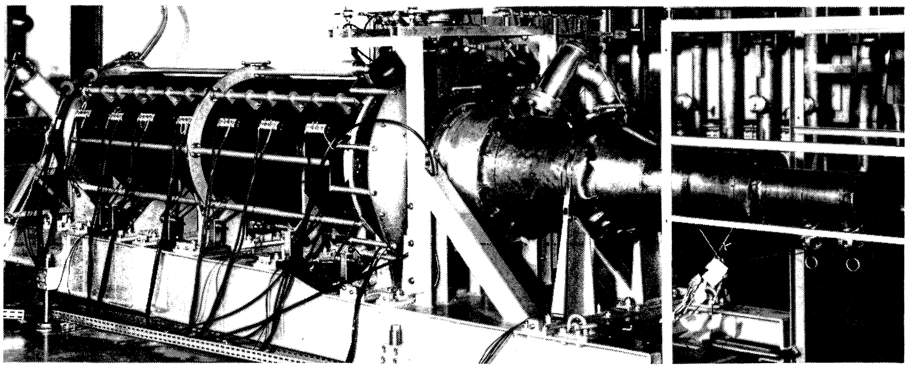
Cooling

In a klystron, the collector dissipates the residual kinetic energy remaining in the electron beam after it exits the interaction zone, but it must, in fact, be capable of dissipating the full beam power, not only for reasons of security but also in the case of a reduction of RF power into the load. Moreover, the distribution of the power dissipated in the collector is not uniform, the power density being at a maximum where the beam edge impacts the copper collector.

Thanks to the use of THOMSON-CSF's advanced Hypervapotron® circulating-water cooling systems, power densities of up to 500 W/cm² at this point can be dissipated without risk. The Hypervapotron technology, including deep but narrow grooves on the collector's outer surface, at right angles to the water flow, makes possible highly efficient cooling without any danger of calefaction and with water-flow velocities not exceeding 2 m/s. The inherent cooling capacity exceeds 1 200 W/cm² of collector inner surface area.

Performance Results Obtained

Development of the TH 2089 "Superklystron" is now well advanced. Extensive testing of the development model tube has already demonstrated a CW output power of over 1 megawatt at a typical cathode voltage of 85 kV — clear evidence of the aptness of the THOMSON-CSF design.



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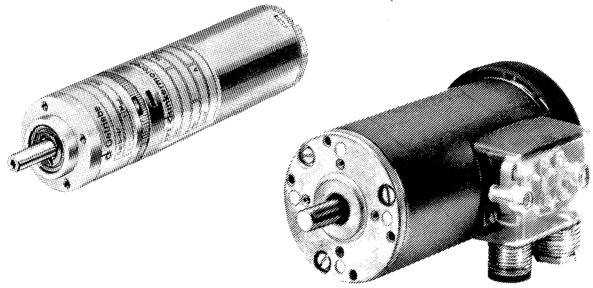

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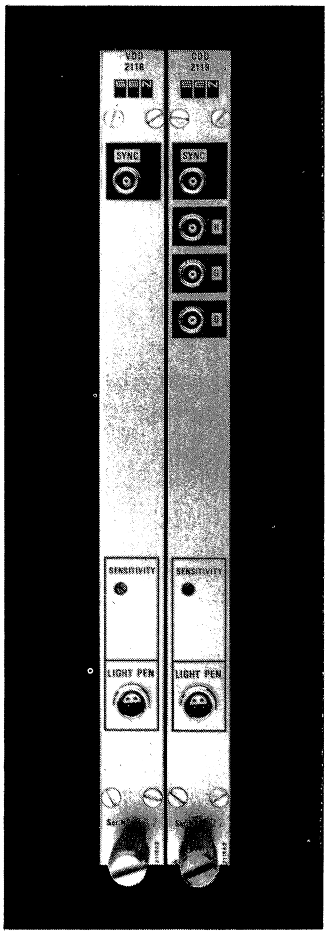

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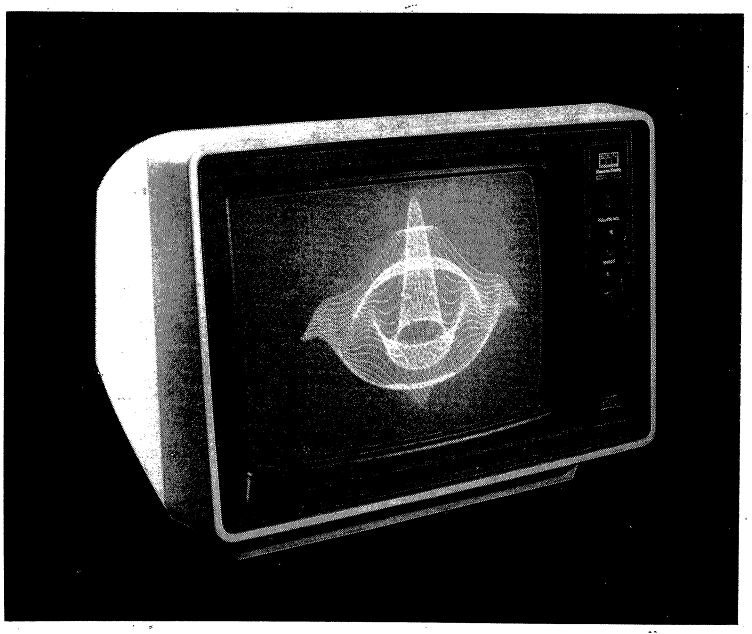

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High sensitivity bialkali 44 mm diameter cathode						

t_r = anode pulse rise time for a delta light pulse
t_W = anode pulse duration FWHM for a delta light pulse

* SIN = Schweizerisches Institut für Nuklearforschung

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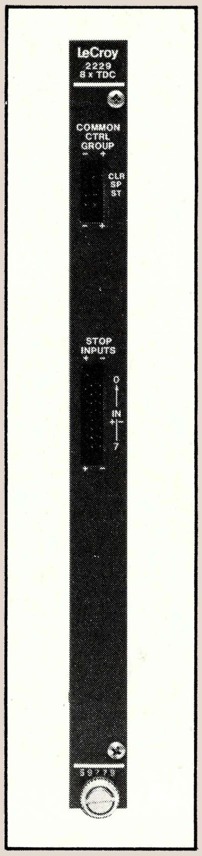
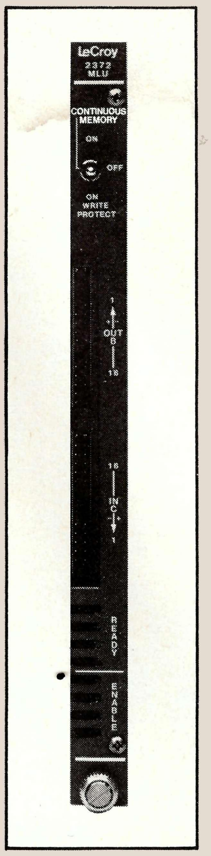


New Additions To ECLine



Model 2229

Octal Time-to-Digital Converter

- *Used for time-of-flight*
- **Eliminates ECL/NIM Adapters**
- **50 psec Resolution, 11-bits**
- **Fast Clear 500 nsec, Effective Synchronous Rate**
- **Full Scale 100, 200, 500 nsec, Switch Selectable**

The Model 2229 is an eight-channel, high performance TDC designed for time-of-flight applications. It employs the ECLine Standard for ECL logic levels and cabling.

The Standard offers the convenience and economy of twisted pair ribbon cable. Use of the high impedance input option greatly simplifies control signal routing, eliminating the need for fan-out modules for Fast Clear, Common Start, and Common Stop signals.

The Model 2229 is pin-for-pin compatible with the growing family of LeCroy ECLine modules.

Model 2372

Memory Look Up Unit

- ***Used for Trigger Processors, Complex Fast Triggers, and Synchronous Applications***
- **Programmable Dimensionality—selects input and output word sizes**
- **High Multiplicity—Up to 16 inputs**
- **Strobed Input Option—simplifies signal timing**

The ECLine MLU is more than just another logic module. It is the fundamental building block of a Trigger Processor and is useful to generate complex Fast Triggers in both beam-on-target and synchronous colliding beam ''gate-clear-gate'' applications.

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For more information contact your local LeCroy representative.

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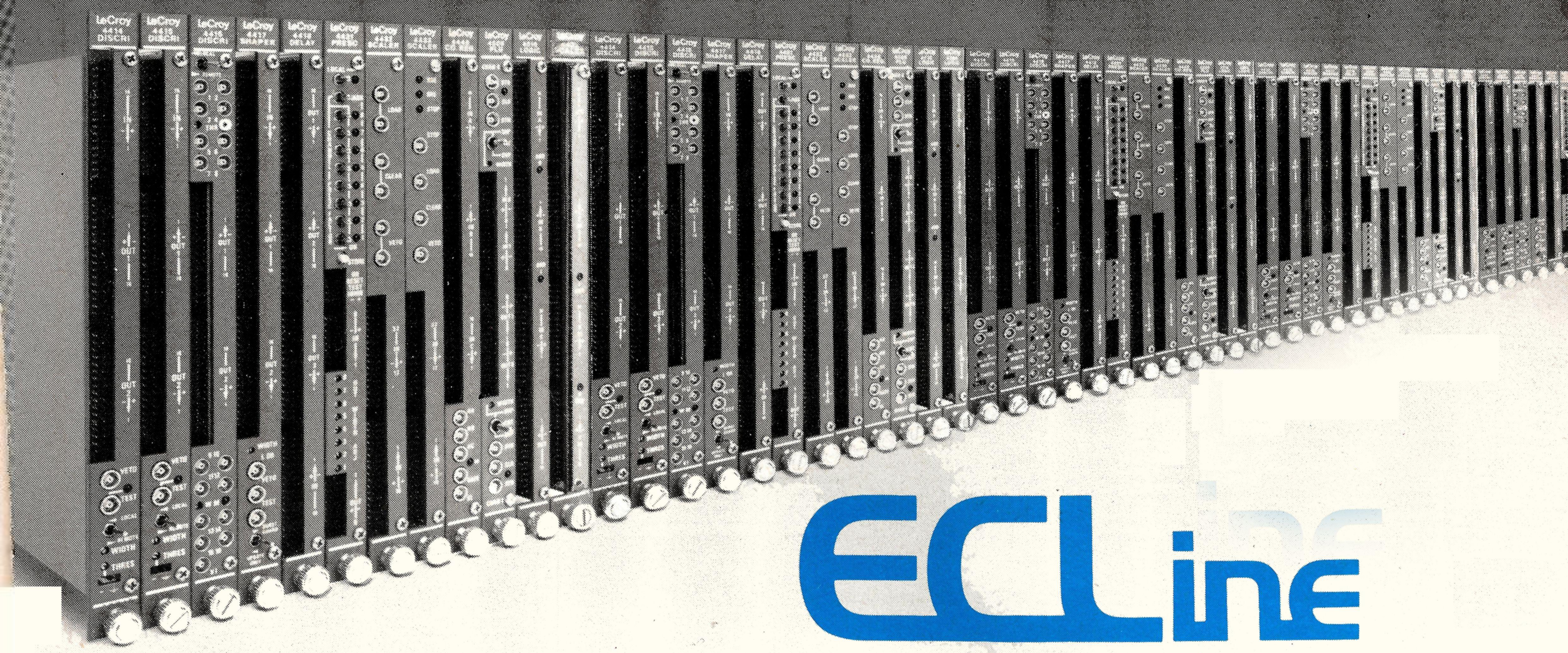

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- 200 MHz, 30 mV min. threshold
- OR output
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- 3 Delay ranges: 16, 32, 128 nsec
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Model 4431: 8 Channel 4-bit Prescaler
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