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Cover photograph: 'Albert Einstein' as seen by the Soviet sculptor Sidor. The sculpture now stands in the coffee lounge at Fermilab. This year marks the centenary of Einstein's birth, and our lead article describes some of the impact of this giant of 20th century physics. (Photo Fermilab)

Albert Einstein

Albert Einstein in 1904, when he was working at the Swiss Patent Office at Bern.

On 14 March 1879, Albert Einstein was born at Ulm in Germany. The centenary of his birth is being celebrated throughout the world and it is appropriate in a journal of high energy physics, a field of research where many of his insights are now the bread and butter of daily work, to pay tribute to this towering figure of modern physics.

In a single year, 1905, Albert Einstein made several dramatic contributions to physics. He deduced the true nature of Brownian motion (doing much to underline the molecular and atomic nature of matter), he demonstrated the particle nature of light in a way which was accessible to experimental investigation (the work for which he received the Nobel prize) and, most dramatically of all, he conceived the special theory of relativity.

From a few simple premises — the constant velocity of light, and the fact that motion is relative with no single object able to claim priority as the 'centre of rest' — Einstein was able to develop relativity theory, one of the man's greatest achievements in pure thought. From this theory emerge such revolutionary concepts as the equivalence of energy and matter, the inseparable nature of space and time, and the extension of lifetime with increasing velocity.

High energy physics Laboratories thrive on the outcome of this theory. The interchangeability of energy and matter, expressed in the most famous equation on physics ($E = mc^2$), underlies the production of the variety of particles which have been studied in the past few decades, and is the source of some of our most essential experimental tools — the secondary particle beams created at the accelerators. It is the relativity effect of increased lifetime at higher velocity that makes many of the experiments possible. The mathematics of the theory with its interlocked space and time co-ordinates, is the bedrock of theory and of experimental interpretation. Yet, not many of these consequences could have been foreseen by Einstein in 1905.

It could be said that other scientists had been on the brink of evolving the 'special theory of relativity' but none were near Einstein's still more revolutionary leap in pure thought ten years later. He emerged with the 'general theory of relativity' bringing gravitation also within the grasp of the theory. It gave the rules for the workings of the Universe on a cosmological scale, superseding the classical work of Isaac Newton which had stood for the preceding two centuries. This opened the door to modern cosmology where there is considerable overlap with the problems and phenomena of high energy physics.

It is appropriate that, on the eve of the Einstein centenary, the most convincing evidence yet obtained for gravity waves — a long awaited consequence of the general theory of relativity — has emerged from studying a pulsar binary system (see page 24).

In the interval between his two great papers on relativity, Einstein made significant contributions to the development of the ideas of quantum theory — in particular with papers in 1913 and 1917 on the emission and absorption of light quanta. However, as the statistical interpretation of Nature took firm hold, Einstein shied away from accepting the behaviour of matter at microscopic level in terms of probabilities. His deep feeling about this is summed up in the famous remark about not believing in a God who plays dice.

From the 1930s until his death in 1955, he devoted himself to evolving a unified field theory which would encompass all aspects of the behaviour of Nature. He had accomplished such a theory with great elegance for all the manifestations of the force of gravity and his vision was to pull the electromagnetic and nuclear forces into a similar broadened theory.

This vision was never realized and it would be fascinating to have Einstein's reaction to the progress in high energy physics in the past few years, where gauge theories are holding out a new hope of unifying our interpretation of Nature.

Albert Einstein left a mark on science as no other person did, even from amongst the most brilliant generation of physicists who flourished in the early decades of this Century. And this mark was felt not only in science.

So great was the impact of his thought and personality that Einstein is synonymous with *the* scientist in the popular imagination. Each budding genius is foisted with his name. His distinctive features are the popular vision of the face of the scientist. Many of the concepts from his relativity theory have now seeped into popular culture.

He had the respect of people from all walks of life. He was blessed with a great love of music and had considerable ability as a musician. He had a deep sense of social responsibility and took a firm stand on many of the important issues which welled up during his life.

His eminence in science, at a time when science and technology were leading to so many changes in everyday life, inevitably led to his being called into the political arena. This had its most telling moment in 1939 when, prompted by Leo Szilard, he wrote the letter to President Roosevelt which initiated the atomic bomb project — an involvement which troubled Einstein for the rest of his life. Another indication of the esteem in which he was held was the offer in 1952 to become President of the State of Israel.

Albert Einstein was a man of great stature both as a scientist and as a human being. He developed a close relationship with the English philosopher Bertrand Russell and a very Russell-like statement, from the 1973 book of Einstein's 'Ideas and Opinions', makes a fitting conclusion to this short tribute — 'The ideals which have lighted my way... have been kindness, beauty and truth.'

Many events are being organized throughout the world to mark the anniversary of Einstein's birth.

The main event is being held in Bern, Switzerland, where Einstein was based when he did his work on relativity. An 'Albert Einstein Centenary' will be held from 13-17 March with a very broad programme covering sciences, humanities, human relations and theology. There is a long list of sponsoring institutions including CERN. Leon Van Hove, CERN Research Director General, is Chairman of the International Committee and many other high energy physicists will be giving papers or chairing session (C.N. Yang, A. Salam, W. Thirring, V. Weisskopf, E.L. Feinberg, A. Zichichi...).

At the Institute for Advanced Study, Princeton, where Einstein worked from 1933, an 'Einstein Centennial Celebration' will be held from 4-9 March. The emphasis is on specific aspects of Einstein's scientific work and many leading figures in high energy physics will be involved (C.N. Yang, W. Panofsky, A. Pais, E. Amaldi, T. Regge, S. Weinberg, P. Dirac, R. Feynman, V. Weisskopf, Y. Ne'eman, G. 't Hooft...).

Some developments in detection techniques and applications

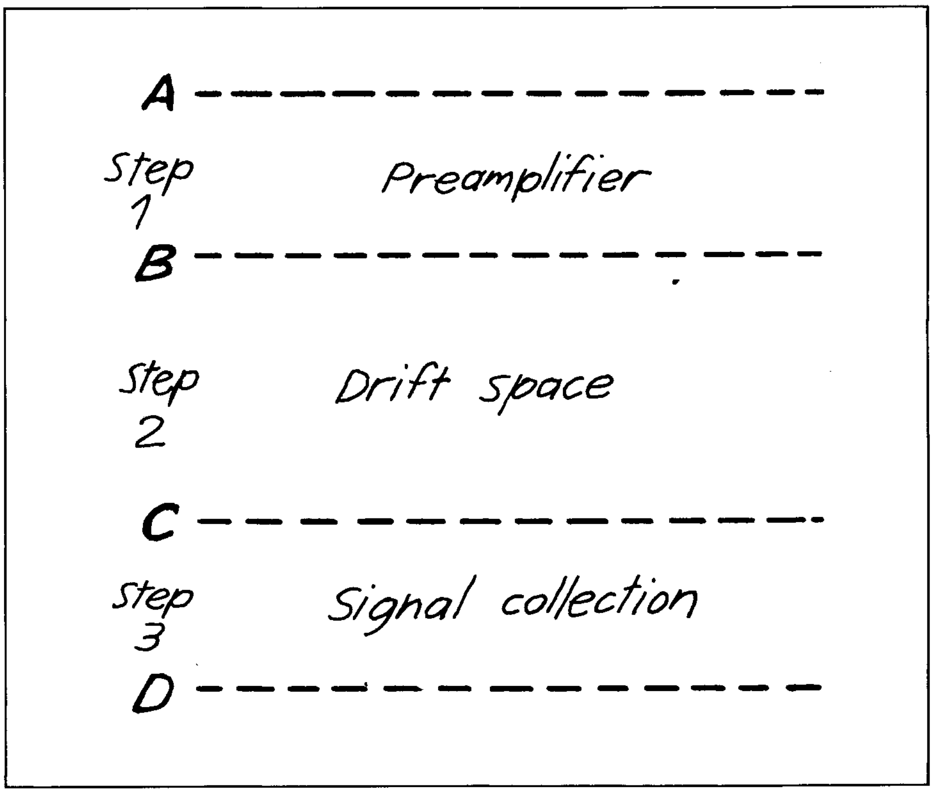
It is a rather obvious statement that developments in particle detection techniques have been crucial to developments in particle physics. It is not only the advancing abilities of accelerators in providing higher energies, intensities and qualities of particle beams that have taken our understanding of the nature of matter further but also the abilities of detectors to untangle the particle interactions which are produced. It is for this reason that every study of a new machine carries with it a study of detection systems to ensure that the new interactions that the machine can reveal will be observable by available detectors.

Since the advent of high energy accelerators, the abilities of particle detection have been revolutionized. The precision with which it is now possible to time the passage of a particle, to locate it in space and to identify it, and the rate at which this information can be collected, are orders of magnitude greater than they were twenty years ago.

As usual, such technological advances, which were pushed in the cause of high energy physics, have also found many applications elsewhere. This article pulls together some recent developments in detection techniques and some indications of applications in other fields.

Multistep avalanche chambers

Perhaps the most significant of all the advances in detection techniques was the invention in 1968 of multiwire proportional chambers and drift chambers by the group led by Georges Charpak at CERN. These detectors locate the ionization initiated by the passage of a charged particle through a gas, either by



The different steps of the multistep chamber which may prove to be another significant advance in particle detection techniques. The role of the various steps is described in the article.

drawing signals from wires closest to the particle (MWPCs) or by measuring the time taken for the electrons liberated in the gas by the particle to reach a wire (drift chambers).

These detectors, now in universal use in high energy physics Laboratories, brought high spatial resolution (1 mm for MWPCs, 100 μm for DCs), good time resolution (25 ns for MWPCs, 500 ns for DCs), multiparticle detection capability, high rate (able to record several million tracks per second), continuous sensitivity to the passage of particles and the ability to draw both spatial co-ordinates from one detector (which has proved of great use in monitoring neutral radiation). Their applications have extended into other sciences (nuclear physics, solid state physics, astrophysics) and the applied sciences of medicine and biology.

There has been a constant effort to improve the abilities of these detectors in many Laboratories and articles and news reports on these developments punctuate CERN COURIER pages for the past ten years.

Now there is particular interest in increasing the rate at which MWPCs can record particles and in improving their accuracy in locating the particle in space. For example, (i) one potential application in medicine, where high energy proton scattering could be used to do three dimensional scans of the body, would benefit from the highest possible rate so as to keep exposure times down, (ii) biological studies using X rays gain from speed and accuracy so as to study living, moving systems, (iii) the new meson factories flood experiments with intense particle beams and are crying out for detectors to keep pace with the beam intensities...

A lot of the steady advance in the abilities of MWPCs has followed the study of the basic physics of energy deposition in gases and the subsequent behaviour of the ionization products. This study has yielded several surprises and the latest one, again unearthed by the Charpak group, could result in another significant step forward.

A major limitation on the possible rate appears to be the result of the length of time needed for the space charge of the positive ions, produced in the region of the signal wires where the electron avalanches are concentrated, to die away.

They decided to investigate ways of reducing this effect. The first trick is to allow only a selected fraction (corresponding to interesting events) of the ionization, initiated in a chamber by the passage of many particles, to develop as a full avalanche. The second trick is to reduce the 'multiplication' in the actual chamber where the signals are collected. The tricks are applied in a 'multistep' chamber in the following fashion.

Step 1 is a preamplifier, with electrode planes A and B, in which the ionization caused by the passage of a charged particle is multiplied by some factor which can be limited to about 10^3. Some of the electrons (perhaps 20%) arriving at the plane of anode wires, B, have been observed to penetrate into the drift space between the planes B and C. In Step 2 the drift time for the electrons to travel between B and C can be set so as to give faster detectors (scintillators and logic elements) enough time to decide whether to record the particle.

When the decision is positive, electrode C is pulsed so as to allow the electrons through into the signal collection chamber between planes C and D. Here, Step 3, there is another stage of multiplication of about 10^3 so that the total multiplication from Steps 1 and 3 is above 10^5 which is the customary figure acceptable to standard MWPC electronics. However, the creation of ions in the signal collection chamber is reduced by a factor of 10^3. In addition, only signals from wanted particles have been allowed through which again reduces the ion creation.

These two manoeuvres, by greatly reducing the ion space charge problem, greatly improve the efficient detection of selected events, amidst a flood of other radiation, such as is often required in high energy physics experiments.

(Detector enthusiasts will probably remark on a similarity with the 'hybrid' chambers developed at Brookhaven and Karlsruhe in 1970. The aim at that time was to reduce costs by combining a MWPC, via a drift space, with a spark chamber where cheaper electronics could be used to draw off the signals.)

When pursuing these ideas, the Charpak group were initially mystified by the remarkably good uniformity and resolution of the transmission process between Step 1, the preamplifier, and the subsequent steps. It was eventually realized that the main mechanism in the transmission does not involve a direct process of charge multiplication but involves the photons produced by inelastic collisions between the electrons accelerated towards the anode plane and the argon atoms in the chamber gas. These photons obviously 'jump' the cathode plane much more easily and their directions are not perturbed by the electric fields. They are of an energy (centred around 10 eV) sufficient to cause ionization themselves in the gas (which is doped with small quantities of easily ionized vapour) of the drift space, liberating more electrons to communicate the signal further.

In the tests at CERN, positional accuracies of 150 μm along the anode wires and 250 μm in the direction perpendicular to the wires (better than the wire spacing given the possibility of interpolating the charge because of the avalanche spread) have been achieved. The rate capability of such multistep avalanche chambers is at least two orders of magnitude better than that of conventional MWPCs. A great deal of further work needs to be done before practical detectors can be built but the results so far are very encouraging.

High resolution streamer chamber

Some ten years ago there was considerable excitement at the development of 'streamer chambers' which offered the possibility of gathering full information about an event, as in bubble chambers, while gaining the ability to trigger on desired events and to have a high data taking rate. The pioneering work was done by the late G.E. Chikovani in Tbilisi following work on wide gap spark chambers by B.I. Dolgoshein in Moscow. By applying high voltage pulses in wide gap chambers charged particle tracks are picked out as a series of short sparks, or streamers, which are not allowed to develop into full discharges by keeping the applied high voltage pulses very short.

The technique was taken up at several laboratories such as DESY and SLAC, where there was some major work with a 2 m chamber. A helium filled version was operated at Argonne and a hydrogen filled version was tried at CERN. A Munich team used a streamer chamber in an experiment at the ISR and large versions, up to 8 m long, have been used at Serpukhov.

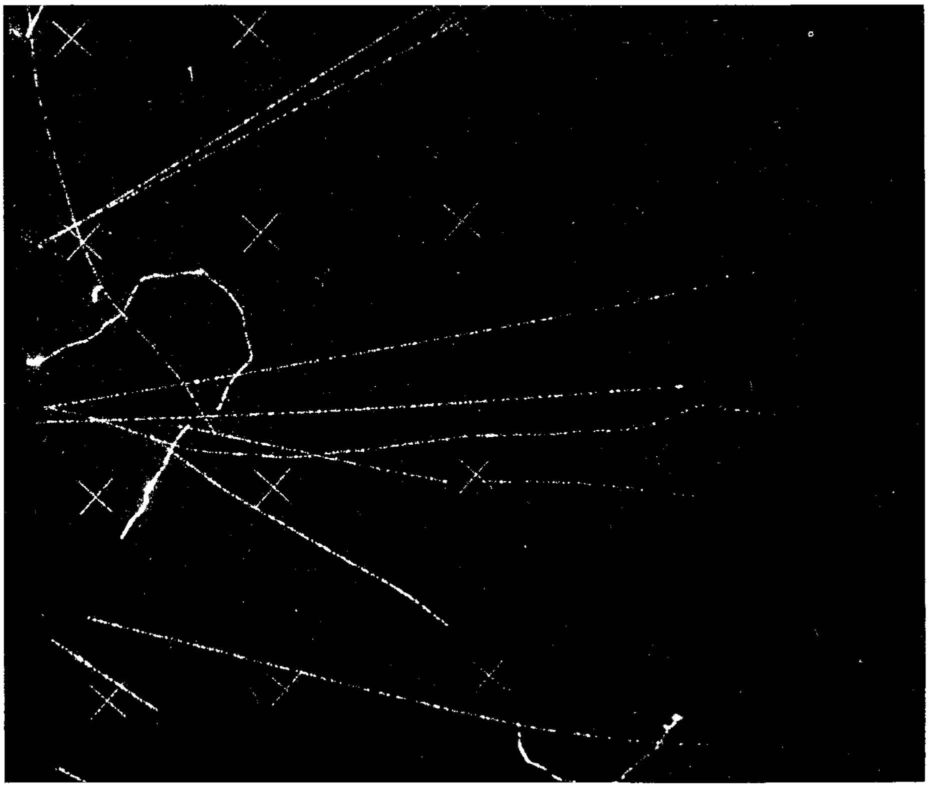
The streamer chamber has not, however, taken over as a universal detection technique. Rather it continues to be applied in particular experiments where its properties are adapted to the particular detection needs. One such application has aroused a lot of interest over the past year. It is the development of a high resolution streamer chamber by the group of Jack Sandweiss at Yale. They have installed their chamber at Fermilab for a (comparatively) high statistics search for charm particles.

The need for high resolution comes from the nature of the charmed particles. Their lifetime, predicted to be in the region of 10^{-13} s, requires good spatial resolution if their short tracks are to be measured. (Up to now, only the emulsion technique has had any impact on this problem.) The Yale team therefore aimed for 10 to 20 μm resolution.

The conventional streamer chamber is of large volume and operates with its gas at atmospheric pressure. Other typical parameters are an applied voltage of 20 kV per cm, an a pulse length of 15 ns. The high resolution chamber is of small volume and is filled with gas under high pressure. To a first approximation, there is a scaling law under which doubling the pressure and the applied field will halve the time necessary to produce a given ionization. Thus the high pressure chamber can collect the same amount of light from much more compact streamers than the conventional type, thus giving the required spatial resolution.

Typical operating conditions for the Yale chamber are a pressure of 24 atmospheres, a field gradient of 300 kV per cm and a pulse length of 0.5 ns (ultraviolet light being used in firing the spark gaps of the Blumlein pulse system, a trick used on the

One of the first photographs taken in an avalanche chamber by a Bologna/CERN collaboration searching for quarks in neutrino interactions at the CERN SPS. The hope is that the 'clean' conditions of neutrino interactions might at last uncover some signs of the elusive free quarks through measurements of primary ionization.



Serpukhov 8 m chamber). The streamer diameter is then some 0.05 mm rather than 2 mm.

The technical difficulties were mainly concerned with the pulse system and the production of transparent electrodes, through which the streamers can be filmed. The electrodes have to carry pulse currents of 3 kA. They are made of 25 μm diameter wire with 100 μm spacing. Two lenses view the interaction volume and are now used in conjunction with image intensifiers rather than film to help eliminate a problem with flare. The usual manoeuvre of adding a little sulphur hexafluoride to the gas gives the chamber of memory time of 1 μs during which external detectors can decide whether to record the event.

In the Fermilab experiments, the triggering is done on muons produced in the semileptonic decay of the charmed particle. Intensities of 10^6 particles per second can be accepted in the chamber and an interaction to be recorded is expected every ten pulses. From amongst them, it is hoped to collect charmed particle tracks at the rate of about a hundred per month.

Two other streamer chamber uses in current experimental programmes are at the CERN SPS. One is installed on the neutrino beamline by a Bologna/CERN collaboration in a search for quarks. Tests with cosmic rays have shown that the chamber, operating in the avalanche mode, can cope with large numbers of secondary particles giving two track resolution of about a millimetre.

To photograph the tracks, the experiment uses the cameras from the old 2 m bubble chamber, now in honourable retirement in a Munich museum. First photographs in the experiment proper were taken using a 200 GeV antineutrino beam just before the completion of the 1978 physics programme at the SPS.

A Bari / Cracow / Liverpool / Munich / Nijmegen collaboration is using a streamer chamber as a vertex detector to record details of hadron-hadron collisions at the highest SPS energies. Data taking is scheduled to commence with the start of the 1979 SPS physics programme, but initial trials show how well the streamer chamber copes with the showers of particles produced at these energies. As well as recording the streamer chamber tracks on film, this experiment also uses on-line digitizing techniques, so that film and off-line computer analysis can proceed in parallel.

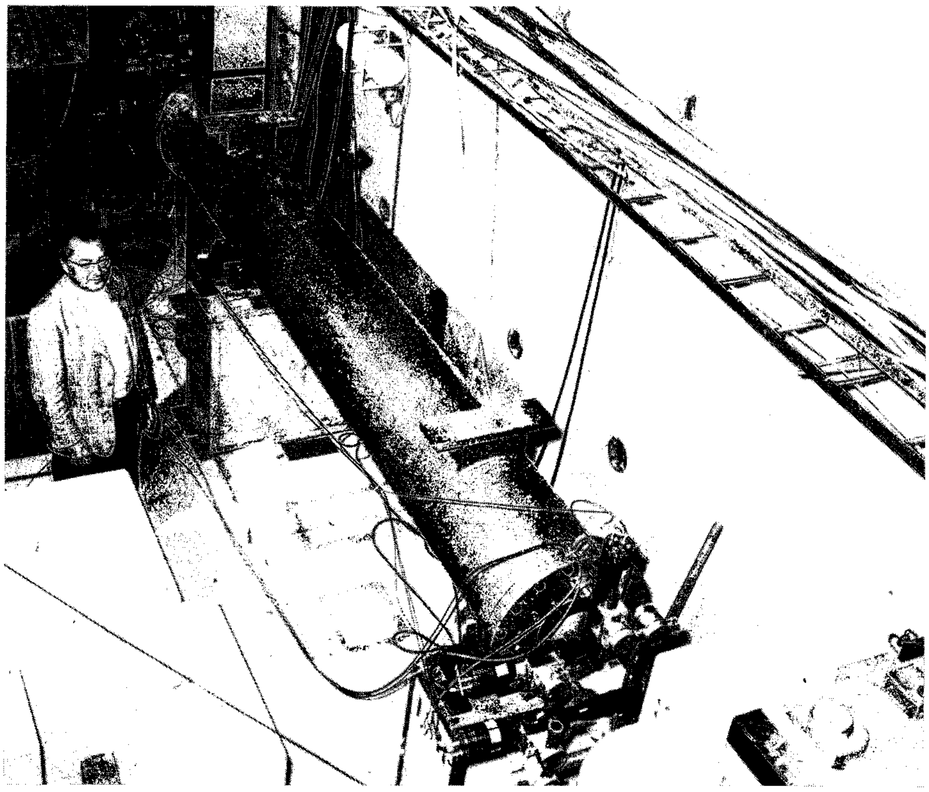
At Berkeley, streamer chambers have found several uses in the nuclear physics programme. A Columbia team took a robust chamber 600 m underground to look for double beta decay (neutrino-less) of calcium atoms in a low background. The chamber was to record two electrons with a combined energy near 4 MeV at an expected rate of one event per day. They have set a lower limit of 1.6×10^{21} years on the lifetime of the double decay process.

In heavy ion work at the Bevalac a streamer chamber has been used by a UC Riverside/Berkeley team to study pion production from nucleus-nucleus collisions. Using a strong magnetic field the pions are easily identified in the photographs. Other heavy ion work is difficult without support from other detectors because of the high multiplicities.

Cherenkov counters have been part of the detector armoury for many years. They make use of the phenomenon of the production of light (in a medium where a particle is travelling faster than the local speed of light) which is emitted at an

R. Meunier alongside the 4 m pressure vessel of the Spot Focusing Detector, a development of the Cherenkov technique.

(Photo CERN 293.10.78)



angle to the particle direction which depends upon the velocity of the particle. The counter can thus be used to identify particles in combination with magnetic fields which curve trajectories depending upon the momenta (mass multiplied by velocity) of the particles.

Spot focusing detectors

CERN has been prominent in advancing the Cherenkov technique. In the 1960s, the DISC counter was developed (allowing particles with velocities very close to one another to be distinguished). In the early 1970s, to cope with high energies, a version involving lenses made of fused silica and sodium chloride was built at CERN by the R. Meunier team and used at Fermilab (see October issue 1973). A more simplified version known as CEDAR, developed by the team of C. Bovet, is now being successfully used in quantity at the SPS (see September issue 1975).

Several groups have been pursuing, in different ways, the idea of gaining both velocity and position information on single particles by focusing the Cherenkov light via a lens system to a spot or small circle of light (hence the title 'spot focusing detector'). The light focuses to a spot for a particular velocity or to a circle of radius depending upon the velocity of the particle. The location of the spot (or the centre of the circle) gives the direction of the particle.

Such detectors could, in principle, handle many particles simultaneously, have high counting rates (10^7 per second), have good velocity resolution (down to one part in 10^6) and reasonable spatial resolution.

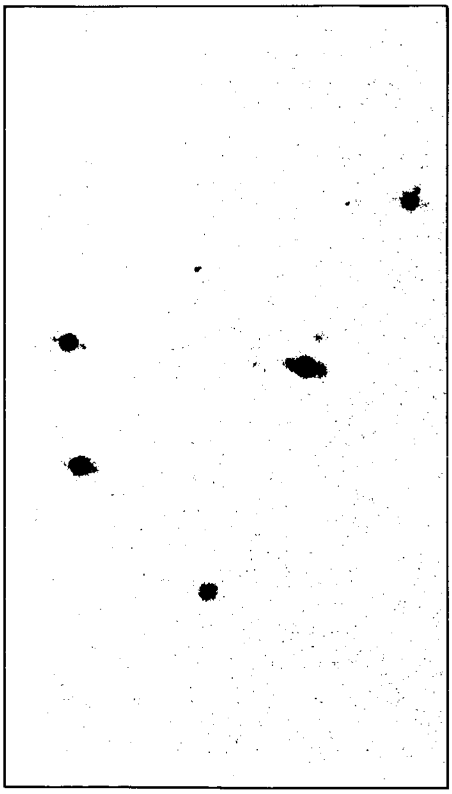
A Bonn group led by R. Giese and G. Schuster saw light corresponding to single particles for the first time in an experiment at CERN (see February 1970 issue). Techniques are being tried, for example, by several groups in the USSR, by a SLAC group led by D. Leith and a Bristol group had some encouraging results at Rutherford just prior to the close-down of Nimrod. The CERN group led by R. Meunier, leaning on the expertise in optical techniques tha they have developed over many years, had some fine results with a prototype at the SPS in December.

The detector was limited in angular acceptance and resolution to keep costs down. It had a 3.8 m nitrogen filled pressure vessel as the Cherenkov light radiator with a maximum Cherenkov angle of 35 mrad so as to have sufficient light input despite the short length. The light detecting matrix had 11 x 11 photocathodes 9 mm in diameter. The optical system had an equivalent focal length of 20 m with a resolution equivalent to that of a DISC producing light rings 1.4 m in diameter!

It is in the optical system that the skill in using this technique is mos important. To gather enough light from single particles within a limited wavelength range while retaining good resolution is not easy. A combination of fused silica and water was used. It had high transparency and small refractive index variation over the wavelength range (230 to 500 nm) of interest. For example, the Cherenkov light transmission at 365 nm was 40% despite three reflections and 28 refractions in the lens system.

Tests were carried out with positive pions, kaons, protons and deuterons in a 50 GeV/c beam. The pressure in the tank, which set the reference velocity for spot focusing, was constantly monitored by a digital refractometer immersed in the nitrogen. Single particle detection

Cherenkov rings obtained using a multistep chamber for detection and amplification of photon signals, followed by an optical spark chamber for visualization. The ring radius determines the particle velocity; the ring centre locates the particle position. This picture was recorded with 1.3 GeV/c protons passing through 5 mm lithium fluoride crystal.



(some twenty photoelectrons recorded for the passage of a single particle, which is good enough in this application), multiparticle simultaneous detection, good velocity resolution (7×10^{-6}), good spatial resolution (0.8 mrad) and rapid response (several ns) were achieved.

This type of detector could have a seful career as a fast trigger counter in particular experimental configurations where the size of the event source is very small and where limited angular acceptance is not a major consideration.

Oddly enough one of the first applications of the multistep chambers described above may be for Cherenkov ring imaging. By using two or three successive stages of amplification in these chambers, the overall gain may be pushed high enough to detect the slightest charge deposition — a single electron produced in a gas by a light quantum could be seen.

Large gains can be achieved in conventional MWPCs, by using gas mixtures carefully blended to supress photoelectric effects which cause spark breakdown, but the light quantum detection efficiency is then deliberately made very small. This is not so in the multistep chamber, where quantum efficiencies above 50% have been measured for photon energies exceeding the ionization potential of an added vapour.

Working together with Tom Ypsilantis, who is based at Saclay and is a pioneer in Cherenkov ring imaging, multistep chambers have been used to yield images of single photons emitted in the ultraviolet range by a fast particle. Although conventional techniques could have been used for the localization of the photons for a quick survey, instead a multistep chamber was coupled to an old-fashioned optical spark chamber (revisiting the Brookhaven work).

Preliminary results show that a velocity resolution around 1% can be obtained for protons in the GeV energy range using a thin lithium fluoride radiator — a rather impressive result taking into account that the whole detector was less than 20 mm thick. A device built on this principle, capable of particle identification over large solid angles, may also add to the experimenter's arsenal.

Detection of neutral radiation

It is in the detection of neutral radiation, X-rays, gammas and neutrons, that most of the 'practical applications', particularly in medicine and biology, have been found. Increased abilities in this area can reduce necessary irradiation times or increase the accuracy of the information drawn from the irradiation. There have been many articles in CERN COURIER on such applications.

At CERN itself, Alan Jeavons has led work on high density MWPCs (as described in March 1977, page 59) building high resolution positron cameras in collaboration with Geneva University. This work has now extended to solid state studies. Georges Charpak has had a continuing interest in X-ray imaging (see October 1976, page 350). MWPCs have also recently been used with X-radiation in the diagnosis of osteoporosis (bone deterioration) by a Rutherford group led by Eddie Bateman. The same disease is being identified using gamma radiation and sodium iodide detectors by a Hebrew University group. We reported gamma work in the UK and at Brookhaven on element concentration in the body (see November 1978 issue, page 402). The list of applications of particle detectors in this field is very long.

Pioneering work on the use of multiwire proportional chambers interleaved with high density material, to obtain good positron detection for gamma and X-ray imaging, neutron radiography and X-ray crystallography, was carried out by the group of Victor Perez-Mendez at Berkeley. Their detectors use lead honeycomb structures coupled with MWPCs for spatial localization of gammas in the MeV range. Their gamma cameras have two large area, large solid angle detectors of this type operating in coincidence.

They ensure efficient conversion of the gammas by the lead honeycomb and yet the lead is sufficiently thin to allow many of the electrons or positrons which are produced out into the spaces where the MWPC can collect signals. Using the back-projection reconstruction method they have good images of bone structures, thyroid phantoms, etc.

and have demonstrated the three dimensional abilities of the camera. Spatial resolution was about 6 mm and the high sensitivity gave 1600 counts per minute per μCi of radiation.

To improve efficiency, the Berkeley team have tried thin walled glass tubes containing a high proportion of lead oxide to build the gamma ray converters. These tubes still give good gamma conversion efficiency, like the lead honeycomb, but the use of glass enables the drift field for the MWPCs to be more uniform. The use of microchannel plate converters of lead-bismuth oxide with hole diameters from 20 to 200 μm, which can give electron multiplication of 10^6, is also being investigated.

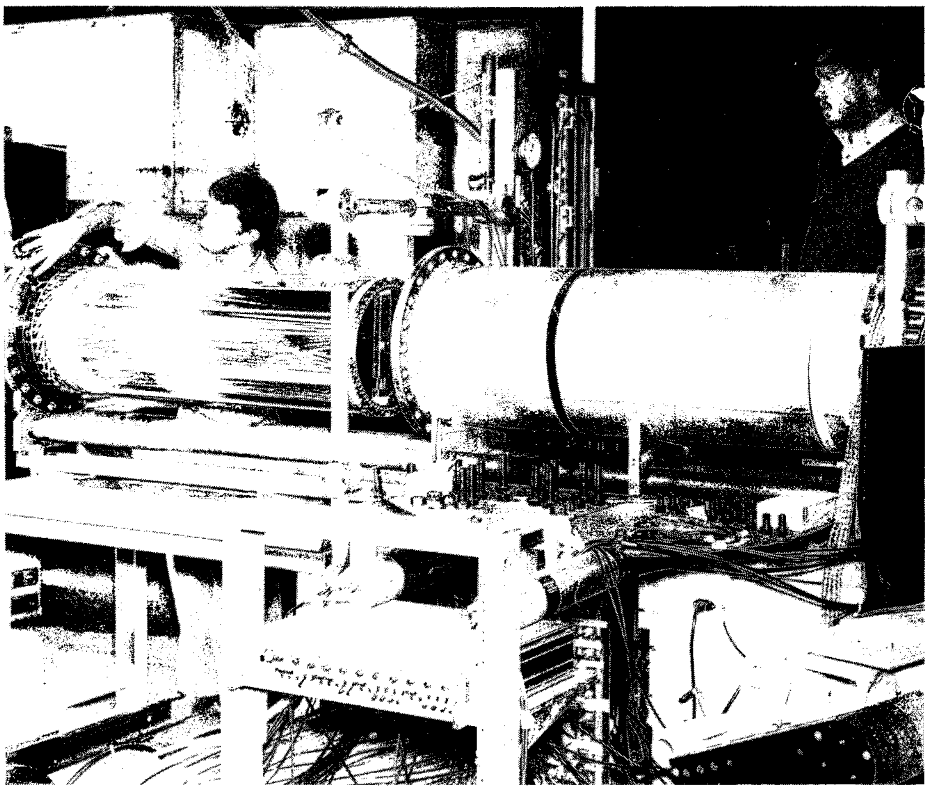
Another topical example of the detection of neutral radiation is an elegant experiment carried out by a Daresbury/Mainz/TRIUMF collaboration at the CERN PS. By measuring soft X-rays in a detector designed by U. Gastaldi, they identified atomic systems which included antiprotons.

Low energy antiprotons were directed into a cylinder of hydrogen (which could also be filled with deuterium or helium). The wall of the cylinder was of thin mylar (6 μm) which allowed low energy (1 to 15 keV) X-rays, emerging from atomic systems which were formed as the antiprotons came to rest in the gas, to enter a drift chamber. This chamber was subdivided into 36 independent cells by having 36 anode wires interspaced with 36 negatively biased wires all stretched parallel to the axis of the cylinder. The aluminized mylar and an outer cylinder were at earth potential. A sensitive gas control system, developed at Mainz, ensured that the mylar was in a stable position throughout a run despite having a range of operating pressures up to 16 atmospheres.

Simultaneous detection of successive X-rays, emitted as the atomic systems decayed through several excited states, and of the final annihilation, producing charged particles (mainly pions) marking the death of the antiprotonic atom, was possible because of the multicell structure. (For further information on the experiment see the August issue 1978, page 257.) For example, three coincident X-rays with energies of 1.8, 3.9 and 11 keV were seen from the atom formed by an antiproton and a helium nucleus.

The key idea in the detection technique was to measure the drift time of the electron produced by the X-ray to reach the anode wire. Zero time was set by the time of arrival of the antiproton in the gas. The probability of the X-ray producing electrons in the chamber increases rapidly with decreasing X-ray energy. Low energy X-rays therefor tend to create electrons close to the mylar and the electrons take longer to drift to the anode. By measuring characteristic known X-rays, the detector could be calibrated.

A new chamber is now under construction for a Mainz/Vancouver collaboration, adding charge division and more appropriate field configurations so that full three dimensional localization of the X-rays can be achieved. It aims to measure the proton-antiproton atomic system in detail as it decays to its ground state.



Drift chamber detector for X-radiation used in a study of antiproton atoms at CERN shown removed from its pressure vessel (on the right). An inner mylar tube 6 μm thick appears wrinkled in the absence of differential pressure. A multicell structure enables many X-rays to be measured simultaneously.

(Photo CERN 175.11.78)

Around the Laboratories

BROOKHAVEN
Charmed baryon

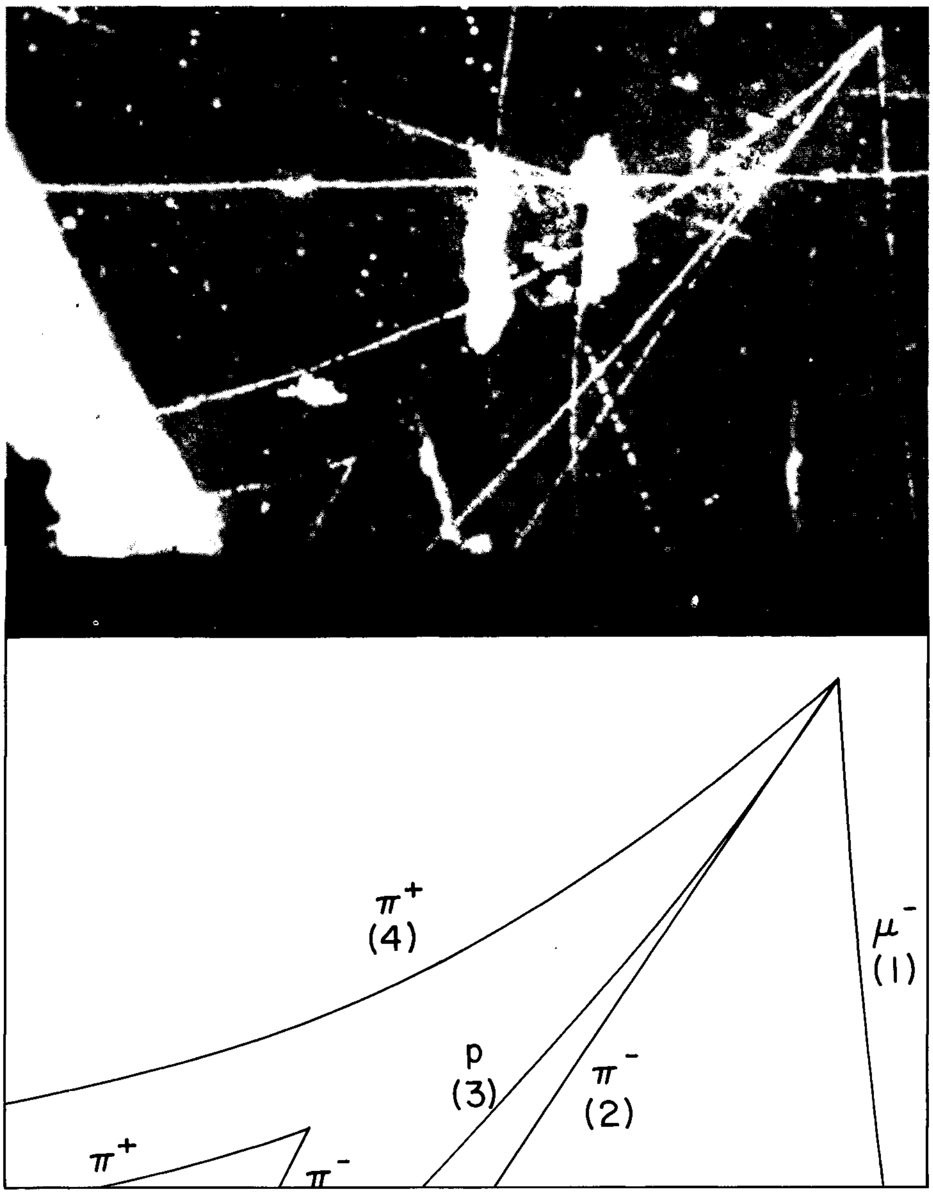
A second example of charmed baryon production has been found in film from the Brookhaven 7 foot bubble chamber. The event was in film taken with the chamber filled with deuterium and exposed to a neutrino beam. The film was analysed by the Brookhaven bubble chamber group, led by Nick Samios.

The photograph shows the formation of the charmed baryon in a neutrino interaction and its subsequent decay cascade, and shows the expected signature of charm production (the hadrons do not change their total strangeness by the same amount as they change their total charge). The baryon, a positively-charged lambda-like particle, has a mass of 2254 ± 12 MeV, in agreement with the mass of the first such charmed baryon observed by the Brookhaven group, and with the results obtained in a photoproduction experiment at Fermilab by a Columbia/Hawaii/Illinois/Fermilab group.

In the second Brookhaven event the charmed baryon was produced directly from a neutron, while the first was the decay product of a doubly-charged charmed sigma-like particle and which decayed through a different cascade (see April 1975 issue, page 108).

The Brookhaven wideband neutrino spectrum peaks near 1 GeV and extends up to 10 GeV, with approximately 14 per cent of the flux above the threshold for charm production. The deuterium fill in the bubble chamber permits kinematic fitting of the final states. This has been crucial in identifying the signature of the two charmed baryon events.

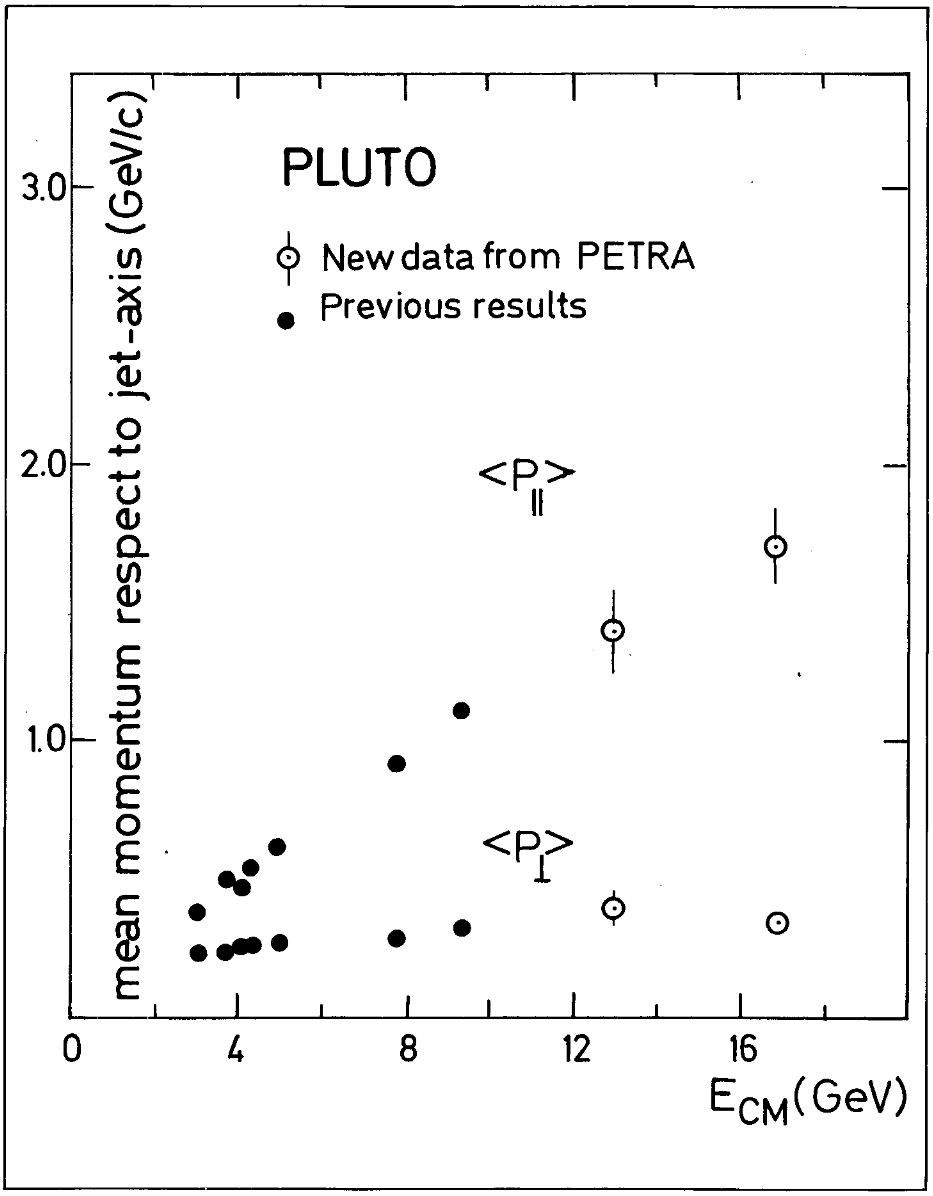
The rate for observed charmed baryon production in the experiment is one per cent of those charged current events which are above the charm production threshold. An event which has a missing neutral in the final state cannot be kinematically fitted and will not be observed. It is difficult to estimate a correction for this loss of charm events but the experimenters point out that their recent results are consistent with the most popular of the current theories of quark flavour dynamics (the GIM model).



Another example of charmed baryon production in the Brookhaven 7 foot bubble chamber exposed a neutrino beam. The baryon, a positively-charged lambda-like particle, has a mass of 2254 MeV, consistent with other measurements on charmed baryon production at Brookhaven and at Fermilab.

(Photo Brookhaven)

Latest data (open circles) from PETRA taken by the PLUTO group. Mean momentum of charged tracks, transverse and parallel to the jet axis, provide further support for jet-type models of hadron production in electron-positron collisions.



DESY
Physics from PETRA

Since November, three experiments — MARK-J, PLUTO and TASSO (see November 1978 issue, page 391) have been taking data at 13 and 17 GeV at the new PETRA electron-positron storage ring for a total of about ten weeks running time. The first results on electron-positron collisions at the highest energies now available were presented at the recent New York meeting of the American Physical Society.

The big question to be investigated at PETRA is the level of hadron production (as usual, compared to the level of muon pair production) at the highest available energy. A significant increase would strongly suggest that one or more thresholds for quark or lepton-pair production had been crossed between 10 and 17 GeV. No such dramatic effect can be detected at present, the hadron production level still being compatible with the value seen at 10 GeV with DORIS.

The MARK-J group has also presented new data on the validity of quantum electrodynamics, continuing an old tradition which started at the DESY synchrotron. The angular distribution for elastic electron-positron scattering at 17 GeV, based on nearly 5000 events, is still in perfect agreement with predictions showing that even the highest available collision energies cannot shake this remarkable theory.

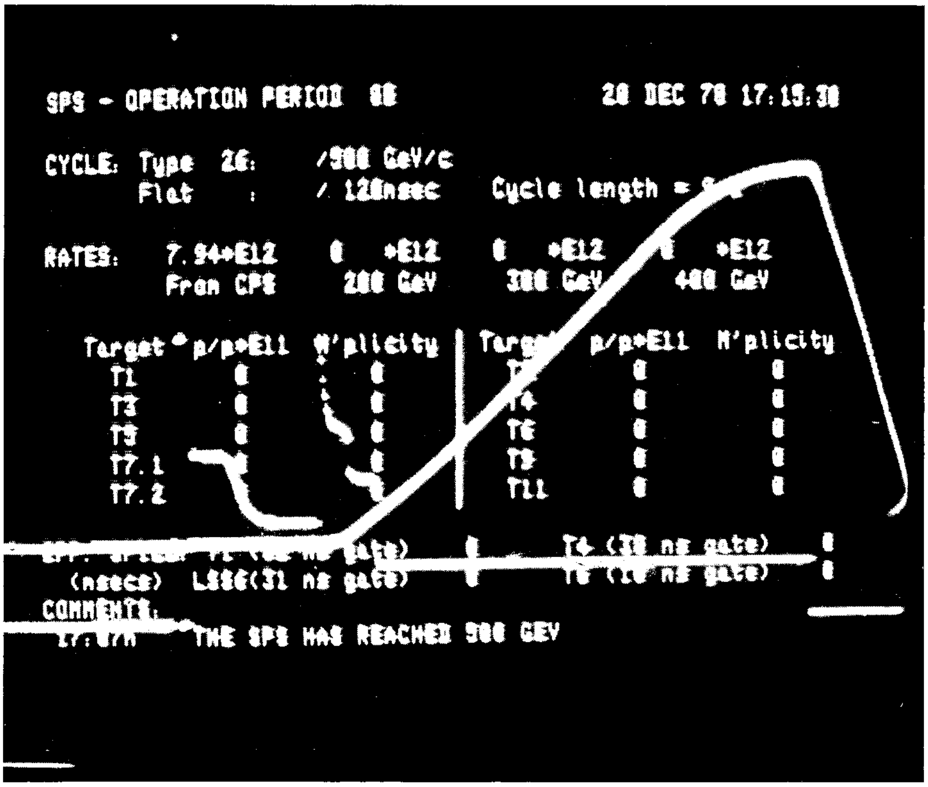
The PLUTO group presented a rather detailed analysis of the multi-body events seen at 13 and 17 GeV. At energies up to 10 GeV in DORIS, the group had shown that hadron production has a two-jet structure rather than a classical phase space distribution. At the higher PETRA energies this is even more evident.

Particles within a jet are expected to have on the average a limited momentum with respect to the jet axis. Data up to 10 GeV did not support this prediction and the mean transverse momentum was seen to be increasing. However at 13 and 17 GeV a plateau is reached, in agreement with the jet hypothesis. Momentum along the jet axis increases with energy, also in line with the jet model.

The PLUTO group has also started an additional line of research in which the tagging spectrometers installed on both sides of the detector along the beam pipe and covering down to 2 degrees have already provided the first data on photon-photon interactions. Coincidences of both spectrometers with two-prong and multiprong events in the central detector were observed.

During the 17 GeV runs PETRA reached a peak luminosity of 1.2×10^{30} per cm^2 per s at each intersection. This is about a fifth of the value expected at these 'low' energies. Although beam currents correspond to the design values, the beam cross-sections are wider than expected due to space charge effects. This is being investigated. In February, more high frequency power was installed to enable the machine to move to higher energies.

CERN PS/SPS run of records



A 500 GeV pulse as recorded at the CERN SPS on 20 December. This record peak energy was achieved in a machine development run and is not intended to be regularly used in physics runs. (One reason for this is the heavy penalty in electrical power, as can be seen from the shape of the magnet pulse near 500 GeV where field saturation has set in). The SPS will, however, begin regular operating cycles at 450 GeV in the course of 1979.

The CERN PS and SPS accelerators ended 1978 with a flourish. In their last run of the year, new records of beam intensity, number of protons accelerated and beam energy were clocked up at the SPS — all of great significance for the physics programme at the machine.

Crucial to the success was the excellent performance of the PS. The new linac injector, which came into action at its full energy of 50 MeV in September, reaching its design current of 150 mA a month later, enabled higher intensity beams to be accelerated through the PS, so that 1.55×10^{13} protons per pulse at an energy of 10 GeV were being sent to the SPS (compared to the previous peak of 1.3×10^{13}). Using two pulse injection, this enabled the peak intensity accelerated to 400 GeV in the SPS to reach 2.1×10^{13} protons per pulse. More importantly, the intensity could be sustained at 2×10^{13}.

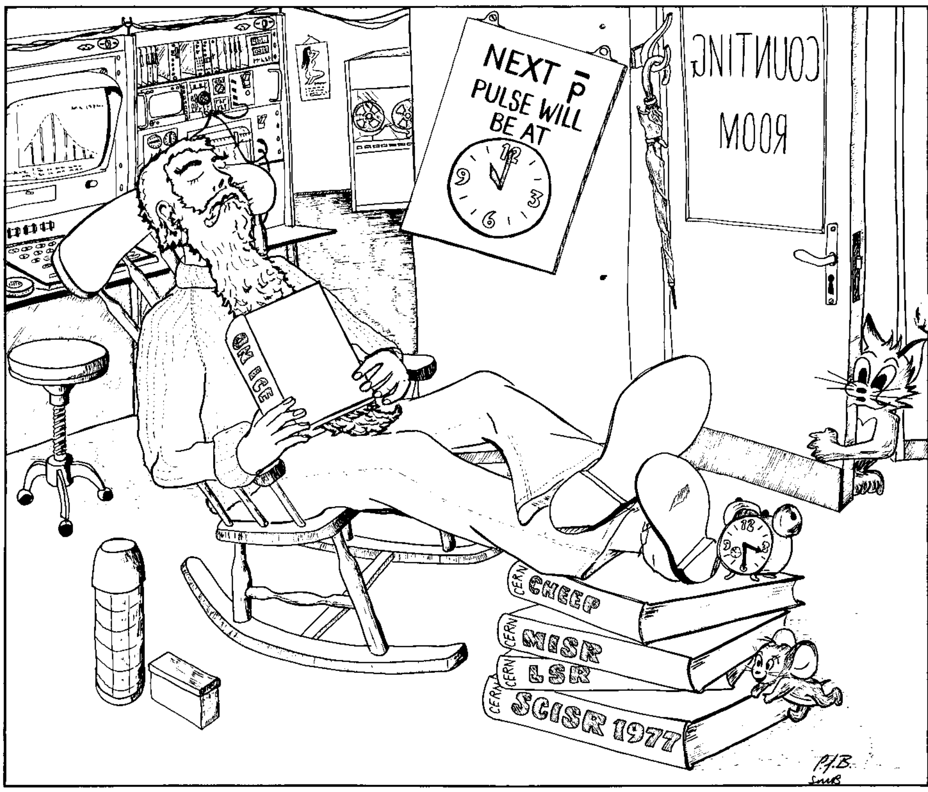
During the six week run, 3×10^{18} protons were delivered to the SPS experimental targets. This meant that over the year, the number of protons fed to the experiments more than doubled compared to 1977 and all experimental areas (North, West and Neutrino) could be operated simultaneously. The SPS efficiency moved to 88% compared to 80% the previous year.

A major aim in machine operation in 1979 will be to consolidate reliable running at 2×10^{13} protons per pulse. This is already a significant step towards the longterm aim of the 'intensity improvement programme' which is to reach 3×10^{13}. However, things get more difficult as the intensity climbs, as colleagues at Fermilab have learned.

After the physics run, a machine development period was used to test the energy abilities of the machine. Here the aim is to establish reliable operation at 450 GeV which is scheduled to begin in June. The installation of a third 90 MVA transformer makes these energies possible. On 19 December, 450 GeV was quickly reached when problems with the electricity supply were cleared. On 20 December, the 450 GeV cycle was repeated, followed by 475 GeV.

The first attempts at 500 GeV were thwarted at 491 GeV due to radial displacement of the beam because of increased saturation of the magnets causing a distortion of the closed orbit in the region of the radial r.f. pick up. A minor change in radial beam position brought 500 GeV and the machine ticked over for an hour accelerating protons to this energy. The SPS thus joins the Fermilab accelerator as the highest energy proton synchrotron in the world.

It is not, however, intended to operate the machine for physics at 500 GeV. The magnets run heavily into saturation, the power requirement is high (e.g. 7.6 kA magnet currents at 500 GeV compared to 4.9 kA at 400 GeV) and reliable



For the proposed scheme to collide protons and antiprotons in the CERN Intersecting Storage Rings (ISR), it will take 24 hours of dedicated time on the 28 GeV Proton Synchrotron to produce just one pulse of circulating antiprotons in the ISR. This motivated Phil Bryant of ISR Division to produce his own interpretation of the control room.

operation of the accelerator could not be guaranteed.

To complete the story of recent PS/SPS achievements, in the last run of 1978 a beam storage experiment was carried out in readiness for the collision of proton-antiproton beams in the SPS which is scheduled for 1981. Beam was sent to the SPS at an energy of 15.8 GeV, above the SPS transition energy which was manoeuvred to below 14 GeV for the test. (The proton-antiproton scheme will avoid the complication of going through transition energy.) This technique proved feasible and will enable stored beams to be studied more easily. Beam was successfully accelerated and stored in single bunches of 8 x 10^{10} protons. This intensity would actually meet the design requirements for the colliding beams but there will then be other different conditions to be met as well.

On 19 February, the eight year '300 GeV programme', authorized by the CERN Council in 1971, came formally to an end. It was gratifying, within time allocated to machine construction, to have comfortably exceeded the design energy and intensity and to have already mounted a thriving physics programme.

New role for the ISR

The CERN Intersecting Storage Rings (ISR), usually associated with colliding proton beams, is to take on a new role, providing experimenters with colliding beams of protons and antiprotons.

There is no fundamental reason which limits the ISR to proton operations. Already some physics has been done using deuterons, and the storage of alpha particles has been studied. The use of antiprotons in the ISR has become possible following the development at CERN of stochastic beam cooling techniques, and the launching of the project to collide beams of protons and antiprotons in the SPS (see September 1978 issue, page 291).

The plan is to produce the antiparticles as a 3.5 GeV secondary beam from the 28 GeV Proton Synchrotron (PS). Each burst of antiprotons will be cooled and stored in the Antiproton Accumulator (AA) ring now under construction.

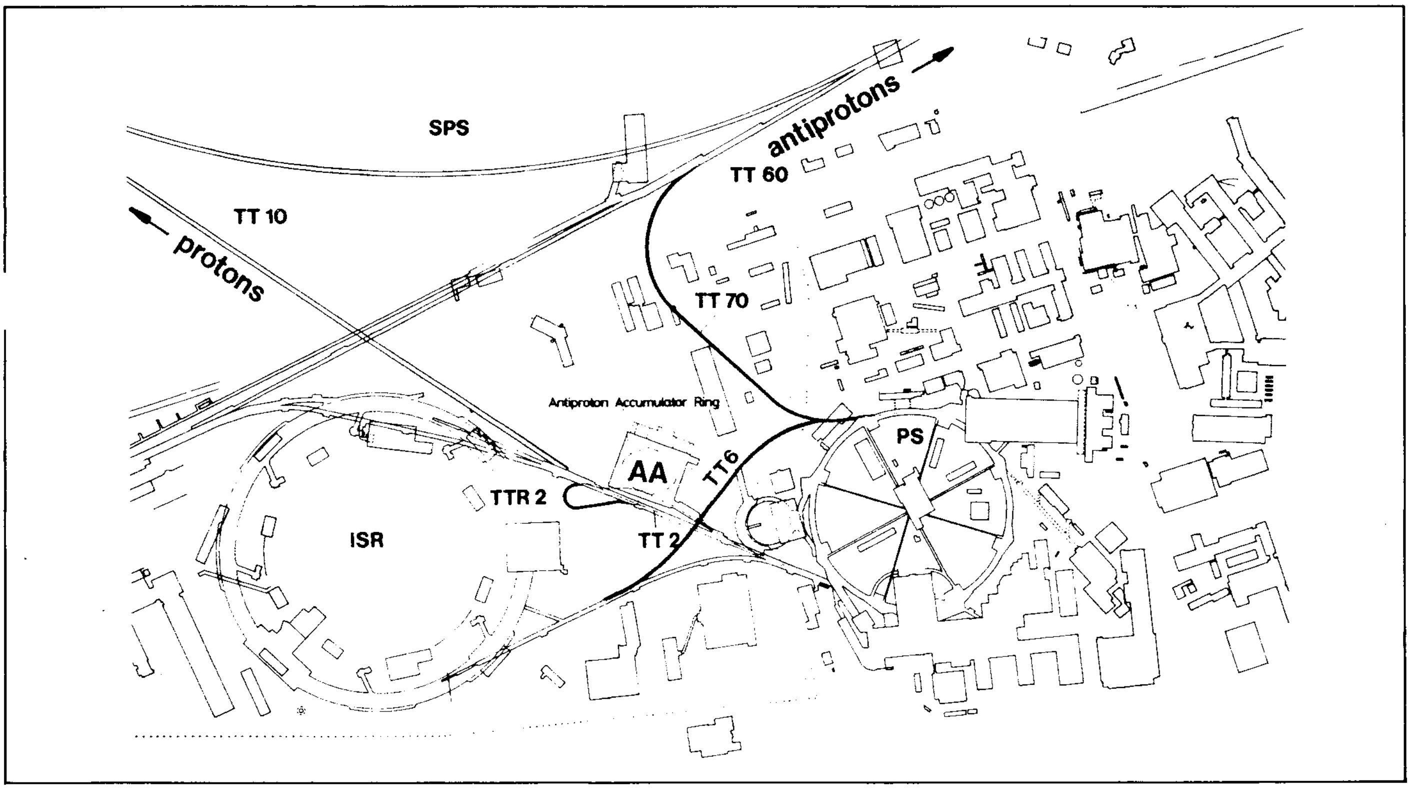
Continuous accumulation of antiprotons over a period of about 24 hours will yield a dense beam of 6 x 10^{11} antiprotons which will be transferred to the PS for subsequent acceleration to 26 GeV. This beam will then be sent to the SPS through a new transfer line, or to the ISR through a second new line.

In the SPS, beams of protons and antiprotons will circulate in opposite directions in the same ring and will be accelerated to 270 GeV before being brought into collision in two underground experimental halls (see page 16). This will provide a collision energy equivalent to that of a 155 TeV fixed target accelerator, a considerable increase over the highest collision energies now available, which are those provided by the 31 GeV beams in the ISR, equivalent to a fixed targed accelerator of 2 TeV.

However even after the new proton-antiproton scheme is implemented, the SPS will still function for much of the time in its primary role as a fixed target accelerator. During these periods the AA ring will be available to the ISR and other antiproton users.

The ISR will be a particularly efficient user of antiprotons thanks to its unrivalled storage capabilities. It will be able to stack antiproton pulses over a period of several days and

Proposed configuration of beamlines for the antiproton project at CERN, which will supply beams of antimatter to the SPS proton synchrotron (through tunnel TT70) and the Intersecting Storage Rings (ISR) (through tunnel TT6).



then continue running with the stored beams for several more days.

At present, ten-day runs are anticipated, with five pulses of 6×10^{11} antiprotons being stacked over four days, followed by a six-day run with stable beams. Data taking will be possible throughout the run except for brief interruptions when new pulses of antiprotons are stacked.

Using this scheme with a 30 A proton beam at 26 GeV, the maximum luminosity in a standard ISR intersection would be 1.3×10^{29} per cm^2 per s, and 9.2×10^{29} with the superconducting high luminosity insertion applied to both beams. This latter figure is not far off the original ISR design luminosity (for proton beams) of 4×10^{30}! Operation will be possible at standard ISR energies and the necessary changes are being made to ensure that all existing experimental magnets can be used.

Another advantage is that equipment destined for antiproton experiments at the SPS could first be tested at the ISR, so that maximum use is made of the limited colliding beam time in the SPS.

It is envisaged that the recently upgraded Split Field Magnet (SFM) at ISR intersection 4 with its very large solid angle coverage, and the proposed open axial field magnet with the superconducting high luminosity insertion at intersection region 8 will play a major part in the ISR antiproton physics programme.

Rather than revealing any totally new phenomena, the ISR antiproton project is expected to open a fresh door on existing physics. Initial experiments will in many ways parallel the first ISR proton-proton studies, but will benefit from the superior ISR instrumentation which has been built up over the years.

Results on total cross-sections and elastic scattering should be available very quickly. Despite an expected rise in the proton-antiproton cross-section over the ISR energy range, the difference between proton-proton and proton-antiproton cross-sections should in fact decrease, but still remain measurable.

This data, together with results on elastic scattering and on quantum number exchange reactions, should provide valuable new information to consolidate our basic understanding of hadron interactions.

For rarer phenomena, the different quark configurations of proton-proton and proton-antiproton interactions could make for useful comparisons (or contrasts) of data to test newer ideas on inner hadron dynamics. This could provide us with valuable insights before results from newer accelerator projects become available.

Model of the proposed detection system for the CERN/Orsay/Pavia/Saclay experiment at the CERN SPS proton-antiproton collider. The search for the intermediate bosons of weak interactions figures high on the list of priorities, although the apparatus will be well suited to a wide range of investigations.

(Photo CERN 211.11.78)

Second intersection region for SPS proton-antiproton collider

1978's rich crop of physics results in line with gauge theory predictions for electro-weak interactions has given fresh impetus to the search for the long-awaited intermediate bosons of weak interactions, which are an integral part of these theories. If the predictions continue to be right, the bosons could be discovered at the proton-antiproton collider being prepared for the CERN SPS.

For this project (described in the September 1978 issue, page 291), a beam intersection has already been booked for an Aachen / Annecy / CERN / London / Paris/ Riverside / Rome / Rutherford / Saclay / Vienna experiment code-named UA1, and work on the underground experimental area is already under way.

Now a second intersection is to be used and a further experimental area will be constructed at straight section LSS4 to house UA2, an experiment by a CERN / Orsay / Pavia/Saclay collaboration.

Obviously the search for intermediate bosons figures high on the UA2 agenda, but as well as looking for the production and decay of these particles the apparatus will be well suited to the study of large angle inclusive particle production and of high transverse momentum phenomena. It will also be able to search for signs of other new particles and for abnormal behaviour such as that seen in cosmic ray studies (see September 1977 issue, page 289).

The experiment will concentrate on the electron decays of the intermediate bosons, rather than those where muons are produced. Electron identification, using lead scintillator sandwich counters, covers a large solid angle with a compact configuration.

Good rejection of hadronic backgrounds is expected, despite the absence of magnetic field in the central region, as a result of the combined use of hadron calorimeters (to veto charged hadrons) and of multiwire proportional counters preceded by a lead converter (to veto neutral pions subsequently decaying into photon pairs). This hadron rejection is essential at the collider energies where much hadronic debris will be produced.

One particular aim is to look for asymmetries in the production of positrons and electrons, such as would be produced by parity violating effects in the decays of the weak bosons. These asymmetries are expected to be large in annular regions around the forward and backward directions, which will be equipped with magnetic spectrometers and segmented arrays of lead-scintillator shower counters.

The spectrometers are designed to be as compact as possible, minimizing the solid angle taken up by the coils, while providing strong bending power.

The inner vertex detector will give precision information on the position of the interaction vertices, and measure the directions of all charged particles. It will be equipped with proportional chambers with cathode strips, interleaved with drift chambers.

The central detector will be made up of 240 independent cells, each containing hadronic (iron-scintillator) and electromagnetic (lead-scintillator) detection components.

In the first phase of collider operation, before the proposed high luminosities are achieved, it is planned to have a 30° wedge cut out of the central detector for installation of a magnetic spectrometer. Electron identification will still be possible in this wedge thanks to a large lead glass wall. This arrangement will permit measurements of inclusive cross-sections and a study of high transverse momentum phenomena.

The experiment demands the preparation and commissioning of a large inventory of equipment, but the collaboration hopes that much of this can proceed in parallel with the implementation of the antiproton project itself. In this way results should be available as soon as possible.

Fixing the charm lifetime

There is now considerable agreement among theorists that the lifetime of charmed particles is something of the order of 10^{-13} s. At laboratory energies, this means that a charmed particle can only traverse about a millimetre before it decays. Nevertheless, it is important to pin down these elusive decays, and a new result from a bubble chamber/ emulsion experiment at CERN provides valuable evidence in favour of present theoretical ideas.

Such short tracks are almost impossible to spot in large bubble chamber photographs where the paths of decaying particles can only be fixed to within a few millimetres. Thus despite the wealth of statistics on neutrino interactions gathered in bubble chambers at CERN and Fermilab, no visible tracks of charmed particles have been seen, suggesting that the charmed particle lifetime is less than 10^{-12} s and is outside the range measurable in bubble chambers. However bubble chambers can detect the decay products of charmed particles (see for instance the excellent example seen in BEBC and published in our November 1978 issue, page 394, and the Brookhaven event on page 11 in this issue).

To record the tracks of the short-lived charmed particles, some other means has to be used. If the charm lifetime is as predicted, then they should be directly observable in emulsion targets. Further downstream detectors facilitate identification of primary interactions and pick up decay products, enabling physicists to pinpoint the region of the emulsion where the decay occurred. Without this, a complete scan of the whole emulsion target would not be feasible.

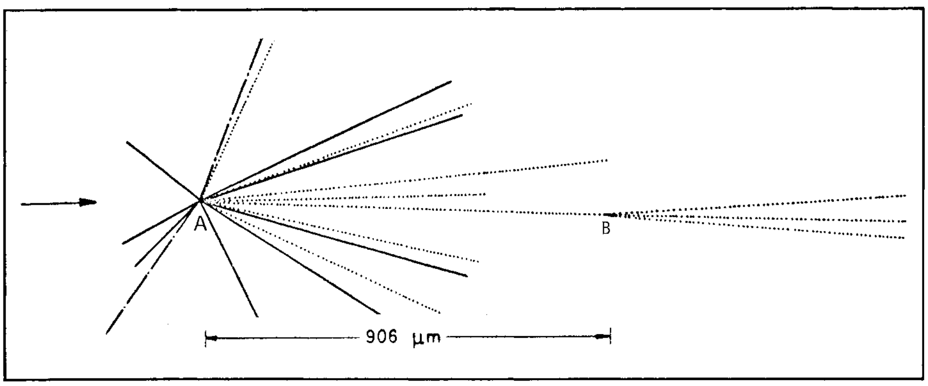
One such experiment uses the CERN Omega detector with emulsion plates exposed to a photon beam (see June 1978 issue, page 208). Other collaborations plan to use emulsion targets actually inside bubble chambers (see October 1978 edition, page 346).

A 1976 experiment at Fermilab, led by Eric Burhop of University College London, exposed an emulsion target to a neutrino beam, using downstream spark chambers to record the secondary products, and found one event consistent with the decay of a charmed particle with a lifetime of a few times 10^{-13} s.

In a second experiment at CERN, an Ankara/Brussels/CERN/Dublin/University College London/ Open University/Pisa/Rome/Turin collaboration, including many of the participants in the Fermilab experiment, has exposed emulsion stacks to the wideband neutrino beam. These stacks were placed upstream of the BEBC bubble chamber.

A wire chamber between the emulsion stacks and BEBC correlated the emulsion and bubble chamber reference systems to an accuracy of 3 mm in the beam direction and 0.3 mm in the other two directions. An additional time coincidence system correlated information from the wire chamber and the BEBC External Muon Identifier (EMI).

So far 168 000 bubble chamber pictures have been scanned for signs of events where at least three high energy particles enter the bubble chamber and point back to a common vertex in the emulsion



Sketch of the charm decay seen in an emulsion/bubble chamber experiment at CERN. The neutrino beam coming in from the left interacts in the emulsion at point A, producing a shower of particles. One minimum ionizing (dotted) track, corresponding to a high energy particle, decays about a millimetre later at the point B, producing three high energy charged hadrons. These are seen in the BEBC bubble chamber downstream. All the evidence points to a charmed particle decay, and the lifetime of a few times 10^{-13} s is in line with theoretical predictions.

target. From these pictures, some 350 charged current neutrino interactions in the emulsion have been identified, and so far 60 have been located. This sample contains one event which shows all the characteristics of charm decay.

It includes, amongst other particles, a negative muon identified by the EMI and a positively charged particle which, after travelling a distance of about one millimetre, produces three charged hadrons which are seen in BEBC. Many interpretations in terms of charmed particle decays involving at least one neutral particle are possible, but the experimental evidence rules out known strange particle decays. The possibility that both this event and the one seen at Fermilab are not genuine is now very remote.

Like the decay seen in the Fermilab experiment, this event also corresponds to a lifetime of a few times 10^{-13} s, well in line with current predictions. Meanwhile the search continues to consolidate the still scanty information on charmed particle decays.

Calculating from Sicily to CERN

The Ettore Majorana Centre for Scientific Culture, founded and directed by Antonino Zichichi, has some seventy schools covering all branches of Science. The schools organize courses on different topics which are normally held in Erice, a historical village in Sicily.

One of the schools is the 'International School of Radiation Damage and Protection' directed by A. Rindi of INFN, Frascati. From 25 October to 2 November, this school organized its second course on 'The use of computers in health physics: calculational techniques in shielding and dosimetry'. The Director of the course was Walter R. Nelson of SLAC, presently at CERN as a visiting scientist.

The calculation of the energy deposited by accelerator beams, or particles from nuclear reactors, in targets or machine components is rather a complicated physical problem. Nor is it trivial to calculate the shielding needed for radiation protection of an accelerator or reactor because of the complex geometries of the radiation sources and the engineering requirements for the shielding itself. It takes a broad knowledge of the physics of particle interactions with matter, of the transport of radiation through different materials, of dosimetry, etc. But these calculations are obviously of vital importance.

Some very sophisticated computer programs have been written, and are widely used, for performing calculations of that type. They can also be applied to many other different problems with possible applications ranging from medical physics to high energy research, from radiation dosimetry to radiobiology.

At Erice, experts discussed with more than forty people of different scientific interests, the physics inherent to their programs, the methods employed in the calculations and their present potential uses. The programs were compared to each other and related to different fields of application either as single programs or combinations of programs.

After eight days of lectures and discussions at Erice, almost all the participants moved to CERN where, thanks to the collaboration of G.R. Stevenson, A. Herz and the Data Handling Division, a Workshop was organized. Together with interested people from CERN, the participants saw the programs in action for the solution of problems in several fields of interest.

The programs were run on the CERN computers and the users, guided by the authors, were able to solve specific problems. The experiment was very successful. Many of the programs presented at the course are now available in the CERN computer files. They cover hadronic cascades, electromagnetic cascades, reactor shielding, unfolding methods, gamma spectrum analysis and detector efficiency and response. For further details of these programs, contact G.R. Stevenson or W.R. Nelson at CERN.

ROME
ECFA LEP Meeting

On 23, 24 November the LEP Working Group of the European Committee for Future Accelerators (ECFA) held its first plenary Meeting in Rome. In the superb Biblioteca Vallicelliana, an important centre of Italian culture in the baroque era, about two hundred scientists from fifteen European countries met to discuss the project to construct a large electron-positron storage ring, LEP.

Antonino Zichichi, Chairman of the Working Group, emphasized in his closing speech that, besides the steady scientific progress toward conceiving a wonderful tool for physics, the Meeting witnessed a strong commitment from the Italian Government to build LEP.

In their interventions, the two most important Italian authorities on scientific matters — Senator Mario Pedini (Minister of Public Education) and the Hon. Dario Antoniozzi (Minister of Scientific Research) — stated that the Italian Government follows the LEP project very closely and hopes that its realization will not be hindered or delayed by extra-scientific matters, as has happened for other European scientific enterprises in the past. For this reason, *At the Rome meeting of the ECFA LEP Working Group, left to right, Jean Teillac (President of the CERN Council), Senator Mario Pedini (Italian Minister of Public Education) and Antonino Zichichi (Chairman of the Working Group).*

Italy does not put itself forward as a candidate to host LEP on its territory and hopes that the choice of site will e made on the basis of maximum operating efficiency only.

The need to ensure that the largest possible number of European high energy physicists are involved in LEP has been repeatedly stressed by Jean Teillac (President of the CERN Council), Marcel Vivargent (President of ECFA) and by Antonino Zichichi. They have pointed out that the present structure of the ECFA LEP Working Group is a good step towards achieving the broadest consensus of the European community on a great scientific venture, which will probably dominate the European scene until the year 2000.

The Working Group heard with great interest the reports from Klaus Steffen and Herwig Schopper on the status of PETRA and on the future plans at DESY. N. Cabibbo, in an interesting talk on theory, emphasized that PETRA results will be of great value for the development of the LEP project.

The scientific level of the plenary sessions was unanimously judged very high. Among the contributions were Wolfgang Schnell's report on the CERN LEP design, N. Bauer's description of the developments in r.f. superconducting cavities, Gus Weber's discussion on experimental areas, Georges Charpak's news of breakthroughs in particle detectors and Prof. Gourdin's analysis of the possible information that LEP will give on the basic mechanisms of the weak interactions.

In addition to the plenary sessions, twenty specialized subgroups, into which the ECFA LEP Working Group is subdivided, met in parallel sessions and set up a detailed schedule for the work to be done. In the final plenary session, the Chairmen of the specialized subgroups briefly reported on the most important subjects they had discussed.

The enthusiasm at the Rome Meeting, the high level of the discussions, and the support of the Italian Government are a good start on the long, hard journey of the ECFA LEP Working Group. The next rendezvous is for 4-6 April in Hamburg.

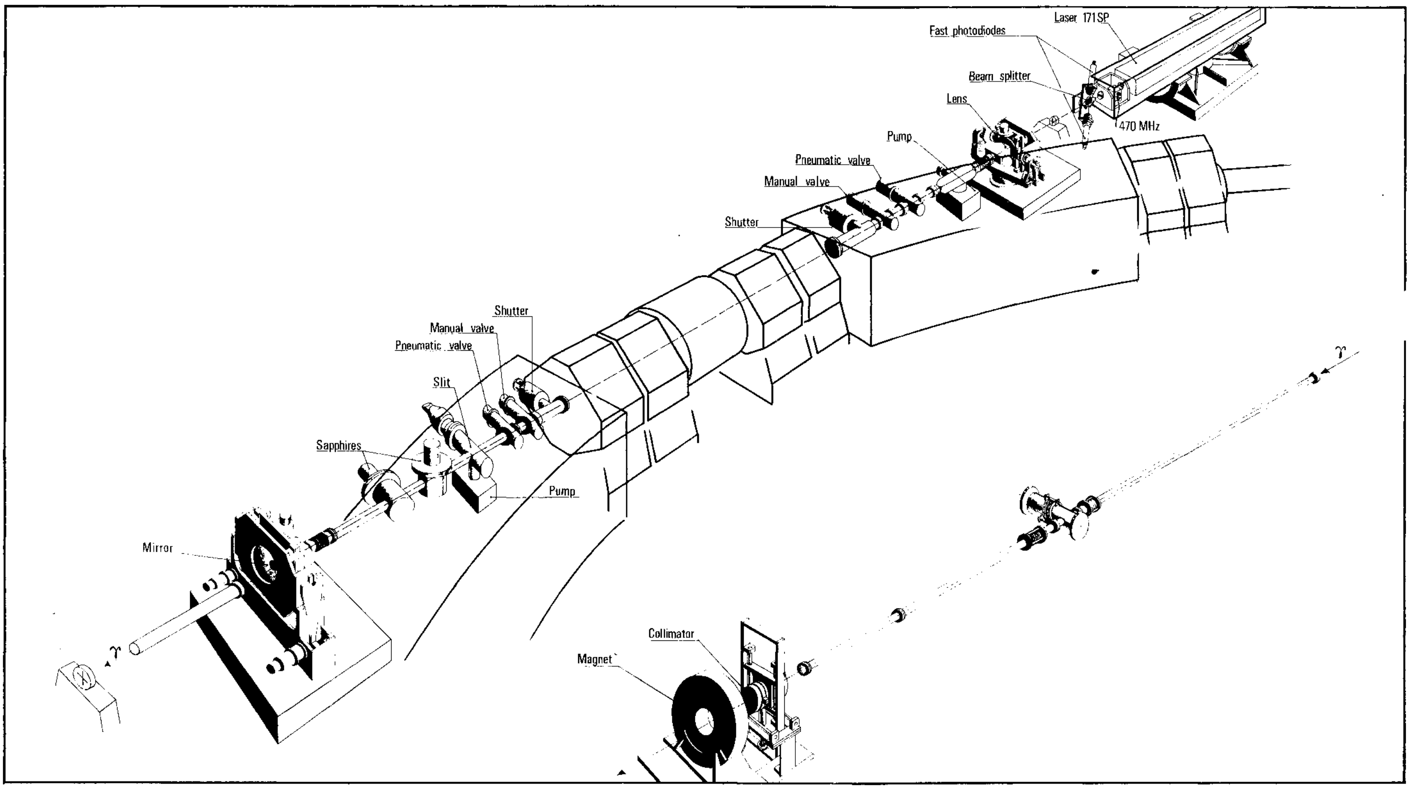
NOVOSIBIRSK
More studies on electron cooling

At the Novosibirsk Institute of Nuclear Physics studies are continuing on 'electron cooling' — the technique of reducing momentum spread in an accelerated beam which was invented at the Institute. Experiments in 1976 had revealed an unexpected effect — the cooling of a proton beam in a typical time interval of the order of 0.1 s which is much faster than was anticipated from the theory.

Investigations have now shown that the sharp increase in the efficiency of the process is due to a marked reduction in the longitudinal spread of the electron velocities after electrostatic acceleration and to the presence of a magnetic field in the cooling section. As a result, the proton interacts in the system of concurrent electron and proton beams, not with a fast electron but with a slowly moving 'Larmor circle'. This reinforces the cooling properties of the electron beam.

During 1977-8 electron cooling has been studied to assess the possibility of using such rapid electron cooling, for example, in antiproton projects. It has been demonstrated experimentally that in the energy range 1.5 to 85 MeV the minimum possible cooling time on the NAP storage ring at Novosibirsk

Layout of the equipment at the ADONE storage ring at Frascati which is used to provide monochromatic polarized photon beams. This facility is now the most advanced of its type in the world.



is independent of the proton energy and has a value of 0.04 s. The limitation on the damping time is due to the effect of the electron beam's space-charge field on the movement of the protons. During the experiments, successful operation was achieved with a betatron oscillation frequency shift of about 0.1.

A feature of this rapid cooling is the steep (quadratic) dependence of the cooling time on the spread in proton velocities. A substantial reduction in the time required to cool a beam which has a large phase space can be achieved by arranging that the electron beam scans the phase space.

This method was recently tested in a series of experiments designed to study the decrease in longitudinal damping. The damping time for a relative proton momentum spread of 10^{-3} was 0.1 s, growing linearly with the increase in the spread (the experiments were performed at a proton energy of 65 MeV and an electron current of 0.3 A).

The results obtained so far indicate that electron cooling is highly efficient over a wide range of energies.

FRASCATI Monochromatic polarized photon beam

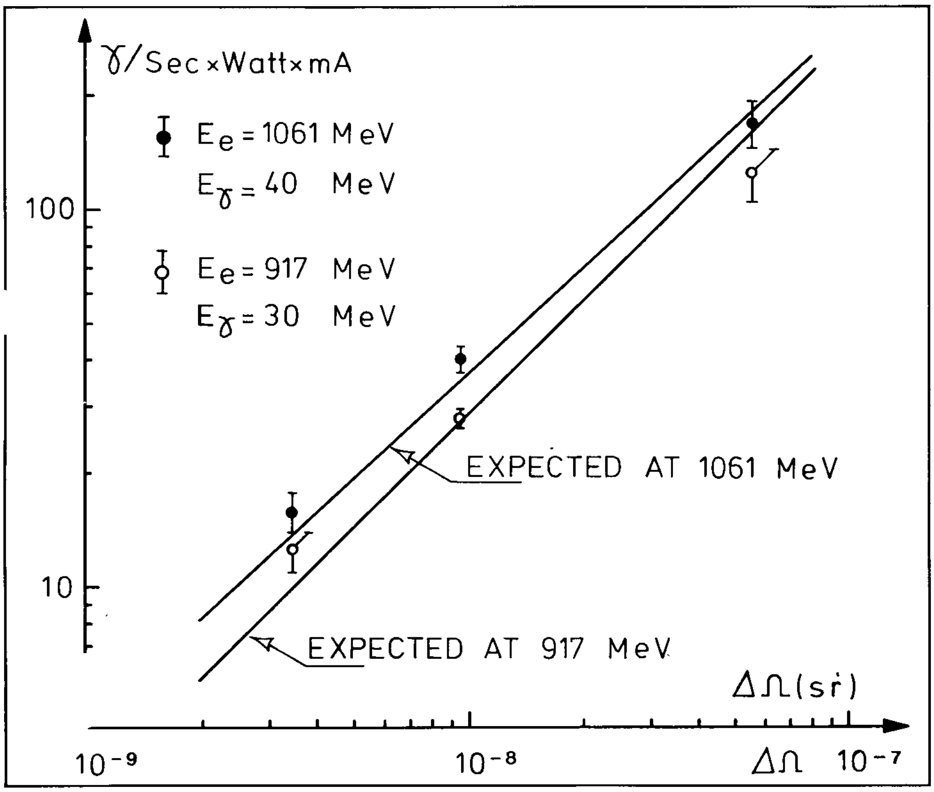
A new monochromatic polarized photon beam has recently been obtained at the Frascati National Laboratories by using backward Compton scattering of laser light against the high energy electron beam in the ADONE storage ring.

Since the usual Compton reaction is a two body process, at fixed electron and photon energies and for a given geometry, the energy of the scattered photons depends only on the emission angle with respect to the direction of the electron beam. Since the differential cross-section is extremely peaked in the backward direction, the photons emerge in a very small cone along the electron beam direction. Beam collimators can therefore select a narrow energy band while preserving high counting rates.

The beam polarization is over 99% which comes directly from total angular momentum conservation and the fact that, for highly relativistic electrons, helicity is a good quantum number.

Additional features are high duty cycle and low background of photons produced by bremsstrahlung of electrons on the residual gas in the vacuum pipe. All these characteristics make this facility the most advanced at present available for the study of photonuclear reactions

Graph showing the excellent agreement obtained at the Frascati photon facility between the measured photon fluxes, at different angles and at two different energies, and the expected design values.



in the intermediate energy region between 5 and 80 MeV.

In the experimental apparatus, an rgon ion laser beam is aligned along the axis of the ADONE straight section No. 2 with an accuracy better than 10^{-4} rad (which is the typical angular divergence of the electron beam). The laser light is injected into the vacuum pipe through an anti-reflecting coated lens and goes to a total reflecting mirror at the end of the optical path. On its way back from the mirror it impinges on the incoming electron beam. The back scattered photons are collimated at 45 m from the middle of the straight section where an experimental hall is located.

A cavity dumping system makes it possible to bunch the laser beam so as to concentrate the electron-photon collisions in the central region of the straight section where the angular divergence of the electron beam has a minimum.

Preliminary measurements have been carried out for comparison with the design parameters. Agreement between expected and observed counting rates is very good over the entire range at different collimation angles and two different electron energies (917 and 1061 MeV). This confirms the hope of obtaining high intensity (about 10^7 photons per s at 80 MeV) when running at a few hundred mA with a laser peak power of 100 W.

For the monochromaticity typical values are expected to range between 0.3% and 1% in the low energy region (less than 10 MeV) but an exact determination of the energy distribution must await operation of a magnetic pair spectrometer which is now in preparation. Nevertheless, a preliminary look in the energy range from 5 to 9 MeV with a germanium-lithium detector (about 60 cm^3) has given spectral distributions. For example, at 9 MeV from the width of the peak and the single and double escape peaks, the beam energy resolution is measured as 1.3% with a collimation angle of 5.5×10^{-5} rad.

SIN
Muon research at the cyclotron

The new meson factories (LAMPF, TRIUMF and SIN) and improvements at existing accelerators (such as the CERN synchro-cyclotron and SREL) have given a dramatic increase in muon beam intensities for muon and muon spin rotation (μSR) physics. Groups from more than twenty-five institutions are now using the μSR technique and many others are doing research in the particle physics of muons.

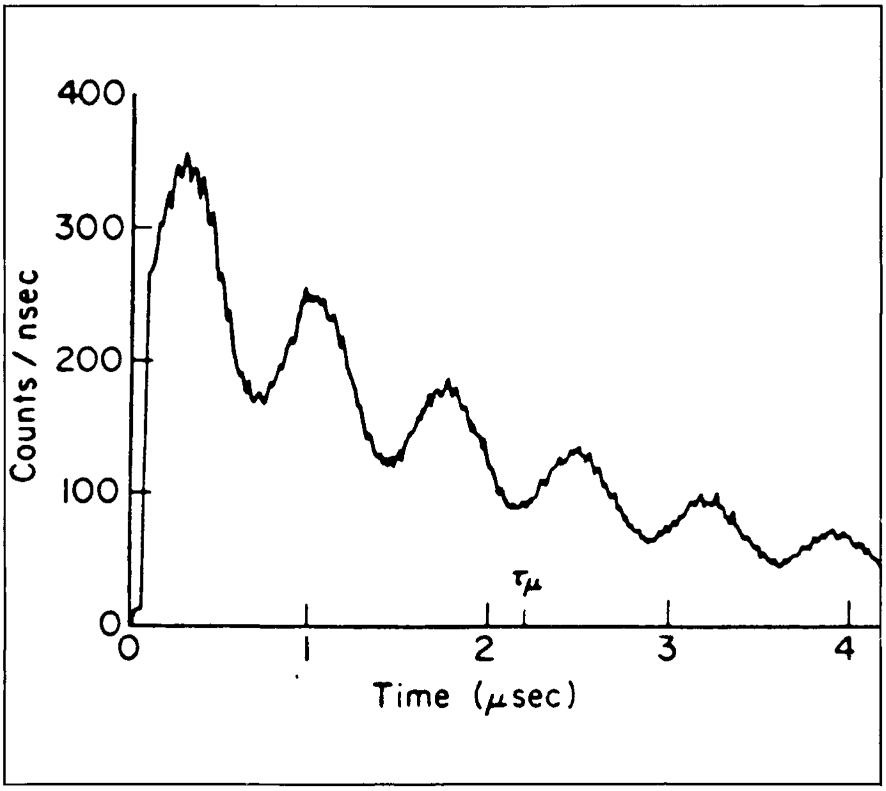
This was highlighted by the First International Topical Meeting on Muon Spin Rotation at Rorschach from 4–7 September. The meeting, sponsored by SIN, brought together many of the principal experimenters.

The muon spin rotation technique

The idea of using positive muons as a probe in solid state physics is as old as the original detection of parity violation in muon decay in 1957. The fact that positrons are emitted from the muon decay preferentially in the direction of the muon spin and that polarized muon beams are available are the two essentials for the technique. The muon beam is polarized along its axis and the most common configuration has a magnetic field applied perpendicular to this direction.

Muons which stop in a target in this field, precess at a frequency dependent on their magnetic moment and on the local field they

The typical form of the signal showing muon decay variation with time in a Muon Spin Rotation experiment. The μSR technique is proving a very sensitive way of probing the properties of matter. It has been opened up much more by the newly available high intensity muon beams.



experience. A positron detector in the precession plane records the decay distribution precessing at the same frequency — an oscillatory counting rate which is also a function of the muon lifetime.

This gives information on the magnetic field experienced by the muon. The variation of the counting rate with time includes a damping function due to the depolarization of the muons in the target which arise from static field spread in the target and / or from dynamical relaxation processes. A static field spread could originate, for example, from nuclear dipole fields, while muon diffusion could lead to a slowing of the depolarization rate.

These effects can be used to study muon diffusion in metals (in analogy to hydrogen diffusion) to observe magnetic effects accompanying phase transitions in ferromagnets, and antiferromagnets, in spin glasses and giant moment systems.

The diffusion measurements can be compared with theory, shedding light on the quantum nature of hydrogen diffusion in metals. The precession frequency measurements give information on magnetic properties at interstitial sites where the stopped muon resides before decay.

Muon physics is of particular importance at SIN, where the muon rates are currently the highest available, thanks to the combined use of the unique superconducting muon channels and the high currents (about 100 μA) of protons from the ring cyclotron. Positive muon stop rates in external beams are up to 10^6 positive muons per gram per square centimetre. μSR groups carry out experiments in all fields described above and have obtained interesting data over the four years since the commissioning of the machine.

Diffusion in metals

The diffusion of positive muons in metals was first observed by V.E. Grebinnik et al. More recent experiments with single crystals of copper by the ETH Zürich group at SIN (M. Camani, D.G. Fleming, F.N. Gygax, W. Rüegg, A. Schenck and H. Schilling) measured the damping rate variation with temperature.

At low temperatures it is constant since the diffusion jump rate of the muon in the crystal is small and the rate is given solely by the static field spread at the muon site. At higher temperatures, the rate slows down and the temperature dependence of the jump rate can be calculated. The dependence in the plateau region on crystal orientation makes it possible to determine the site and the lattice dilation around the muon.

Surprising results have been obtained by the same group with high purity single crystals of niobium indicating an anomalous temperature dependence. A narrow dip near 20 K is new and disappears with high interstitial impurities. This has been interpreted by a two stage diffusion process.

Similar complexities in the temperature dependence have been found in other metals. A Heidelberg / Stuttgart group (K. Dorenburg, M. Gladisch, D. Herlach, H. Metz, H. Orth, G. zu Pulitz, A. Seeger, H. Teichler, W. Wahl and M. Wigand) have investigated the precession damping in monocrystalline high purity metals from 2.5 to 400 K. Beryllium and tantalum have a plateau in the damping around 100 K and 40 K, respectively, with a decrease on both sides of the plateau. In beryllium the decrease continues down to the lowest temperature measured (2.5 K) whereas tantalum seems to increase again below 10 K.

Further work on positive muon diffusion in metals at even lower temperatures may lead to the clear detection of quantum effects. Muon diffusion may well have advantages for such investigations over hydrogen diffusion because of the lighter muon mass.

Investigation of internal magnetic fields

The internal field seen by the muons is the sum of the external field, the demagnetization field, the Lorentz field, the magnetic field from dipoles within the Lorentz sphere and, finally, the contact hyperfine field due to the conduction electrons. The temperature dependence of the internal field for a single cobalt crystal has been measured by an ETH Zürich / Univ. Zürich group (H. Graf, W. Kündig, B.D. Patterson, W. Reichart, P. Roggwiller, M. Camani, F.N. Gygax, W. Rüegg, A. Schenck, H. Schilling and P.F. Meier).

At temperatures below 450 K where the easy axis of magnetization is along the hexagonal c-direction, the internal field is first negative, decreasing smoothly to zero at 460 K. It changes sign abruptly between 500 and 600 K because of a rotation of the easy axis of magnetization from the c-direction into the basal plane (known from neutron diffraction studies). At 690 K a phase transition in the crystal structure occurs and the value of the internal field increases by a factor of two.

For five years prior to the Rorschach meeting, the investigation of interstitial magnetic fields had been carried out for ferromagnetics, antiferromagnetics, rare earths, insulators and various alloys and compounds. The results provoked intense theoretical activity and it is clear that this technique will produce interesting data for years to come.

Positive muons and muonium in insulators and semiconductors

A complete session at Rorschach was devoted to the study of insulators and semiconductors with positive muons, which is also a major field of research at SIN. μSR experiments in silicon have indicated three types of muon state namely μ^+, Mμ and Mμ*.

The μ^+ component consists of those muons which fail to pick up an electron or find themselves for other reasons in a diamagnetic environment. Mμ represents the state of a muon and electron, i.e. a paramagnetic state like muonium in vacuum but with reduced hyperfine interaction. Mμ*, originally observed at low temperatures, is an anomalous muonium state. The Zürich / Konstanz group (B.D. Patterson, A. Hintermann, W. Kündig, P.F. Meier, F. Walner, H. Graf, E. Recknagel, A. Weidinger and Th. Wichert) obtained high statistics in a μSR experiment with silicon and have established that this anomalous state is well described by a spin Hamiltonian with axial symmetry. A further experiment by the Konstanz group with undoped germanium saw a similar state.

Muonium chemistry in gases and liquids

The first direct observation of muonium in a liquid was obtained in 1976 by the ETH group Zürich as a first stage in a programme of liquid phase muonium chemistry. Measurements of how quickly the muonium precession signal disappears in a number of aqueous solutions disagree with earlier indirect determinations, while comparisons with the rate constants for hydrogen atoms reveal large kinetic isotope effects.

Another first for SIN in μSR research was a recent experiment of the Zürich University group (E. Roduner, P.W. Percival, D.G. Fleming, J. Hochmann and H. Fischer) who report the first direct observation of muonium substituted transient radicals. They have observed muon precession frequencies in dimethy butene at various fields.

Signals attributable to radicals were also found in other substances and, for isoprene and pentadiene, two different radicals were observed.

The coupling constants yield the electron spin densities at the muon, which can be compared to the hydrogen analogous radicals. They appear to be considerably larger for the muonium substituted series. This can be understood in terms of an isotopic rotational averaging which gives information on intramolecular fields and dynamics.

(More on muon research at SIN next month).

Late News: on 1 February Fermilab had proton beam through a main ring sector of 25 superconducting magnets.

Physics monitor

Gravity waves

Apart from the reconciliation of the theory of gravitation with quantum physics, one of the few problems which remained in Einstein's monumental contribution to physics — the general theory of relativity — had been the detection of gravitational radiation.

Reports of the observation of gravity waves have come and gone over the years, but it is fitting that a confident new claim has been made in time for the year of the centenary of Einstein's birth (see page 3).

This latest observation ties in with the 'classical' experiments earlier this century which verified the general theory of relativity. This means that despite the numerous modifications which have been proposed over the years, the observed behaviour of gravity is exactly as predicted by Einstein in his original version of the theory.

In Einstein's formulation of general relativity, some solutions of the field equations have the properties of waves. These gravity waves travel at the speed of light and are similar in some respects to the electromagnetic radiation described by Maxwell's equations. They are produced by the acceleration of mass in much the same way as electromagnetic radiation results from the acceleration of electric charge.

However as far as we know, mass is always of the same sign, while electric charge can be either positive or negative. This means that gravitational radiation is detected through quadrupole rather than dipole effects.

Gravitational waves should produce minute tidal effects in objects in their path, and early attempts to detect the radiation concentrated on picking up this motion of the detecting equipment.

The expected magnitude of gravitational resonance in laboratory equipment is so small as to pose apparently insurmountable observational problems. For a metal bar one metre long, the induced movements due to gravity waves could be smaller than the diameter of a nucleon. In the face of such observational problems, some other way had to be found of detecting the waves.

Since they carry energy, gravity waves would sap the energy of an accelerated body, such as a continuously rotating binary star. Such a star was discovered in 1974 using the 300 m diameter fixed radio telescope at Arecibo, Puerto Rico. One of the rotating stars is a pulsar and, by careful measurements of its timing, astronomers were able to determine all the parameters of this rotating system.

This huge double star rotates with a period of about eight hours and pumps out gravitational radiation at a comparable rate to our sun emitting electromagnetic radiation, and its characteristics make it an ideal 'laboratory' for general relativists. Initial results confirmed general relativity effects hitherto seen only in planetary systems.

The continual loss of energy through gravitational radiation should affect the period of rotation of the system and a team, led by Joseph Taylor of the University of Massachusetts working at the Arecibo telescope, has been able to monitor these tiny variations using precision equipment.

The observed change in the orbital period is just one ten thousandth of a second per year. This is exactly the prediction of general relativity, and means that the study of gravitation has entered a new field of dynamical behaviour.

Hot spots discussed at Bonn

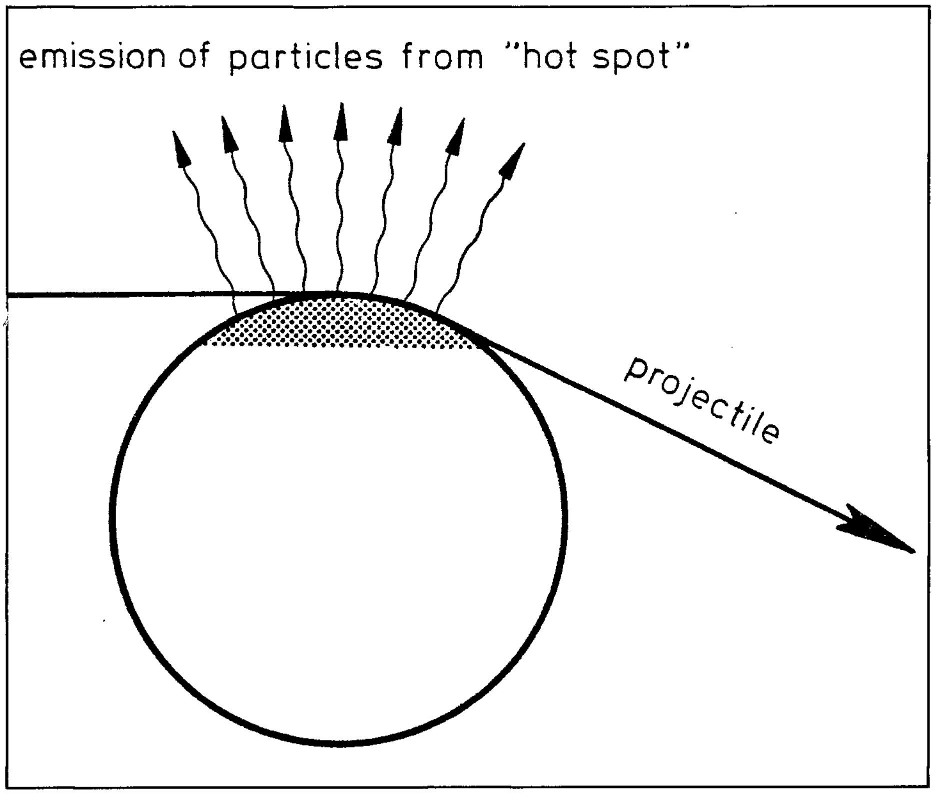
Is it reasonable to talk about a fraction of a particle or nucleus? Is there an 'up' and 'down' in such microscopic systems? A short time ago such questions appeared meaningless or, at least, highly speculative but this is changing.

By reformulating the questions — Can we localize excitations in a particle or nucleus? Is such a localization observable? — we begin to see positive answers from three independent experiments performed recently in Europe, Israel and Japan. The importance of this development for nuclear and particle physics is that it becomes feasible not only to follow the space-time evolution of a reaction but also to gain new information about nuclear matter (especially heat conductivity) which was not previously accessible to experiment.

The starting point of these developments were theoretical studies (particularly by R.M. Weiner) at the University of Marburg from 1974. New effects were predicted as a consequence of local excitations called 'hot spots'. These studies were supported in part by DESY, Los Alamos and Deutsche Forschungsgemeinschaft.

When two particles or nuclei have a glancing collision, it is expected that at first only their surfaces will be excited. Theoretical considerations suggest that this excitation will propagate rather slowly into the interior of the system and any emission of particles should therefore occur before the excitation has spread over the whole system. Since the excitation is only local, this emission takes place from a limited region which leads to a space asymmetry in the emission of particles.

The 'hot spot' effect, in a particle or nucleus, where a glancing collision creates a local region of excitation. Results from three recent experiments indicate that such effects have been seen and could provide an additional way of learning some particle and nuclear properties.



Such an asymmetry can be seen in a coincidence experiment which detects one of the scattered particles and an emitted particle. Observing the scattered particle gives the asymmetry direction and, from the magnitude of the asymmetry, interesting information about transport properties in nuclear matter as well as about the size of the excited region can be obtained. In this way, the concept 'fraction of a particle' gets some scientific meaning.

The recent experiments involved particles (Israel Institute of Technology) and nuclear systems (Max-Planck-Institut für Kernphysik, Heidelberg/Centre de Recherches Nucléaires Strasbourg/Institute of Physical and Chemical Research, Wako-Shi). In all three experiments the asymmetries are consistent with the hot spot mechanism.

Although a complete understanding of hot spots needs much more elaborate experimental and theoretical investigation, at present this kind of localization of excitations seems the simplest explanation of the observations. This was a conclusion from an international workshop organized by Bonn University from 15-17 November. Further experiments are being performed at various institutes including Berkeley and Darmstadt.

GSI Darmstadt has recently submitted a proposal for the construction of a high energy heavy ion accelerator and a similar project is under study at Berkeley. Such high energies are necessary to investigate hot spots with all their consequences. One of these consequences is the possibility of achieving extremely high temperatures (trillions of degrees!) in very small volumes. At present the highest temperature obtained in the laboratory is a million times smaller.

People and things

On people

At the December Session of the CERN Council, Jean Teillac was re-elected President for 1979 and Paul Levaux Vice-President. Gunther Lehr was elected Vice-President in succession to A.C. Pappas. Other re-elections were of M. Gigliarelli-Fiumi as Chairman of the Finance Committee and Godfrey Stafford as Chairman of the Scientific Policy Committee for 1979. In the SPC also, the membership of Willie Jentschke was renewed and Sheldon Glashow was elected as a new member. Within CERN, reappointments were made of Robert Lévy-Mandel as Directorate Member for Budget Planning and Site Management, Jacques Prentki as Leader of Theoretical Physics Division and M. Tièche as Leader of the Finance Division.

At the end of the Council Session, Leon Van Hove recorded the thanks of CERN for the work and devotion of three Directorate members who have come to the end of their term of office. Erich Lohrmann is returning to DESY and the University of Hamburg and is succeeded by I. Mannelli. Franco Bonaudi returns to his work in developing large detection systems in collaboration with experimental teams (this time on the proton-antiproton collider at the SPS). He will be succeeded by Michael Crowley-Milling. Paul Falk-Vairant is returning to the University of Paris and is succeeded by V. Soergel.

At the request of Fermilab Acting Director, Phil Livdahl, the Director Designate, Leon Lederman, is now responsible for decisions relating to experiment proposals and long term scheduling of the Laboratory's physics programme.

1. Kenneth Robinson
2. M.W. Teucher

Kenneth Robinson, formerly of the Cambridge Electron Accelerator Laboratory, died on 10 January. He was a key contributor to the design of the electron synchrotron and achieved world renown as an accelerator theorist. He became specially known for his contributions to beam stability (Robinson criterion), his work on radiation damping and quantum excitation in electron storage rings and on coherent synchrotron radiation. Together with G.A. Voss, he invented the low-β insertion which has become standard in colliding beams. After the closedown of the CEA in 1973, Kenneth Robinson retired from active life and moved to San Diego.

Professor M.W. Teucher died on 26 December at the age of 57. He had been a member of the DESY Directorate for many years and was well known at CERN as a leading bubble chamber physicist. His scientific career began with cosmic ray experiments using emulsions, extending to systematic studies of high energy interactions with multiparticle production. While based at Hamburg University, he joined the DESY Directorate in 1962 and strongly supported the construction of electron-positron storage rings. At CERN, he promoted the use of bubble chambers for the study of neutrino interactions and was Chairman of the Track Chambers Committee. He was a proponent of the construction of the Big European Bubble Chamber and had the satisfaction of seeing BEBC in action with neutrino beams from the SPS.


1.

Sir Brian Flowers, former Head of the Science Research Council and UK delegate to the CERN Council, was made a life peer in the Queen's New Year Honours List. Sir Brian is at present Rector of Imperial College London.

Rolland Johnson has been put in charge of a new Fermilab subdivision to handle the 400 GeV programme.

On 3 November, Yi-ichiro Nambu, Professor of Theoretical Physics at the University of Chicago, received the Order of Culture from the Japanese Emperor for his contributions to the theoretical progress of particle physics. The Order of Culture is the highest award in Japan for cultural achievement and is given to eminent scholars and artists each year on 3 November which is the Day of Culture (a national holiday). Professor Nambu graduated from the University of Tokyo and subsequently worked at Osaka City University. In 1952 he went to the United States and has become an American citizen, making this the first occasion that the Order has been given to a foreigner. Other recipients of the Order of Culture in the field of particle physics are H. Yukawa and S. Tomonaga.


2.

A Memorial Fund has been set up under the sponsorship of IN2P3, CERN and the French Physical Society to establish a series of lectures dedicated to the memory of Bernard Gregory. They will be devoted to subjects of broad interest for the general public or more specialized themes for physicists. Anyone wishing to make a contribution can do so via a special account (No. C7–100-250 'Fonds Bernard Gregory') at the Société de Banque Suisse, CERN, 1211 Geneva 23. Any correspondence about the 'Bernard Gregory Memorial Fund' can be addressed to Dr. Owen Lock at CERN.

Norman Venn, who retired from the Rutherford Laboratory in 1976, died suddenly on 17 November at the age of 63. He worked at Rutherford for fifteen years, latterly as Head of the Nimrod Division.

Sergei Yessin, who is in charge of the Soviet 650 MeV meson factory to be built near Moscow, recently led a Soviet delegation on a three week visit to Los Alamos to study the LAMPF accelerator and its research programme.

Louis Rosen, Director of LAMPF, had some strong words to say about communication of science at the LAMPF Users meeting on 13 November. 'We do beautiful science. We do miserable public relations... I appeal to you to do more than we have in the past in making the nature of our work un-

Just ten years ago, ground was broken for the linac at the future Fermilab. In December 1968, Bob Wilson (left) and Glenn Seaborg posed for the camera brandishing the shovel used in the ceremony.

(Photo Argonne)

derstandable to the Congress, to the administration and to society at large.'

Samuel Goudsmit, former Chairman of the Physics Department at Brookhaven, died on 4 December at the age of 76. Among the major achievements of his physics career was the discovery of the electron spin together with George Uhlenbeck in 1925 for which he received many scientific honours. He was Chairman of the Brookhaven Physics Department from 1952 to 1960 and Deputy Chairman until 1967. Goudsmit was also Editor of The Physical Review from 1951 to 1962 and founded Physical Review Letters in 1958 remaining Editor until 1974.

Gerard 't Hooft was awarded the 1979 Dannie Heineman Prize for Mathematical Physics at the APS meeting in New York on 30 January. The citation read, 'for his contributions to quantum field theory, in particular for his studies of the renormalization and other features of non-Abelian gauge theories, all represented by outstanding publications in the field of mathematical physics.'

A two volume book in Russian by B.P. Murin, B.I. Bondarev, V.V. Kushin, and A.P. Fedotov (edited by B.P. Murin) on linacs has been published by Atomizdat. It is aimed at those involved in the design and development of accelerators and at graduates or undergraduates majoring in the field. The book extends to up-to-date topics such as simultaneous acceleration of protons and negative hydrogen ions and the novel proposal of asymmetric alternating gradient focusing in linac structures.

More money for science

It was announced in December that the science budget in the UK is to be increased by £47 million over the next four years. Perhaps more significant than the sum of money involved, is the fact that this represents a turn around in the financing of scientific research after many years of progressive cuts.

More than 70% of the extra money will go to the Science Research Council, headed by Professor Geoffrey Allen, which is the source of funding for high energy physics, amongst other disciplines. It is likely that some of the new money will go to speeding the completion of the Synchrotron Radiation Source (SRS) at Daresbury and the Spallation Neutron Source (SNS), laser and electron beam lithography facilities at Rutherford.

During their visit to Stanford to discuss cooperation between US high energy physics Laboratories and the Institute of High Energy Physics in Peking, the Chinese visitors gave a banquet for the assembled delegations. In the photograph (left to right) Luke Yuan of Brookhaven, Lin Tsung-tang of Peking and Pief Panofsky of SLAC share a toast.

(Photo Joe Faust)

China–USA collaboration in high energy physics

An important delegation from the People's Republic of China visited the USA in January for discussions concerning collaboration between the new Institute of High Energy Physics in China and American high energy physics Laboratories. The delegation consisted of Lin Tsung-tang (Chief Engineer at the Institute), Lu Hian-lin (Deputy Director), Hsieh Chia-lin (Head of Accelerator Design Division), Chou Bein-long (Deputy Chief Engineer), Jan Zhen-chiang (Mechanical Engineer), Yin Tzi-lie (Electronics Engineer), Hsu Shaw-wang (Assistant Chief Engineer) and Li Chang-fu (Head of Foreign Affairs Division).

A meeting took place at SLAC on 15–19 January and the collaboration possibilities with Fermilab, Brookhaven, Argonne, Berkeley and Stanford were discussed.

On 27 April, an 'International Symposium in Honor of Robert R. Wilson' will be held at the Fermi National Accelerator Laboratory. The programme will reflect the broad culture of the former Fermilab Director with talks on 'History of accelerators' by W. Paul, 'Beauty and the quest for Beauty in science' by S. Chandrasekhar, and 'Science and Art' by V.F. Weisskopf. Other speakers will be L. Lederman and H. Bethe. This is an open meeting and anyone requiring further information should contact Judy Ward, Fermilab, P.O. Box 500, Batavia, Illinois 60510.

Collision Workshop

The First Workshop on Ultra-Relativistic Nuclear Collisions, jointly sponsored by the Lawrence Berkeley Laboratory and the Gesellschaft für Schwerionenforschung at Darmstadt, will be held at Berkeley on 21–24 May. The Workshop will consist of a relaxed schedule of discussion and talks covering the experimental and theoretical understanding of high energy (over 10 GeV/nucleon) hadron-nucleus and nucleus-nucleus collisions. The focus will be on using this information to see what new fundamental physics can be obtained from studying high energy nuclear collisions. Further information can be obtained from the ARC Office, Building 51, Lawrence Berkeley Laboratory, Berkeley, California 94720.

Meetings

Los Alamos Scientific Laboratory will host a LAMPF Program Options Workshop to examine critical questions in nuclear and particle physics and how they can best be investigated through the use of intermediate energy accelerators. The meeting will be held in Los Alamos on 20–31 August. Panel membership is by invitation; plenary sessions are open to all interested persons. Further information may be obtained from John C. Allred, Mail Stop 830, Los Alamos NM 87545, USA.

A National Conference on Synchrotron Radiation Instrumentation will be held at Maryland from 4–6 June. Further information may be obtained from D.L. Ederer or E.B. Saloman, Radiation Physics Division, National Bureau of Standards, Washington D.C. 20234, USA.

Electron-proton Study

On 2-3 April a 'Study of an electron-proton facility for Europe' will be held at DESY. It is being organized jointly by the European Committee for

Memory man Hans Eberstark in action at CERN.

(Photo CERN 125.12.76)

Future Accelerators (ECFA) and DESY. Colliding electron-proton beams has been debated in the USA and in Europe for several years (see for example November 1977 issue, page 364) and, following the decision to pursue a very high energy electron-positron machine as Europe's major project for the 1980's, ECFA decided to reassess the physics interest of an ep machine and to clarify the relevant technical problems.

The first day of the Study will be given to the technical aspects: a review of ep projects, a presentation of the possibilities and limitations of these colliders, state of the art for superconducting magnets, a round table on the technical problems associated with the different approaches.

The second day will be given to the physics potential: assessing the validity of ep physics with working groups on new particles and new currents (discussion leader L. Sehgal), large Q^2 physics and hadron structure (D. Perkins), small Q^2 physics and photoproduction (M. Green) and looking at the detection problems for neutral current events (M. Holder) and charged current events (K. Tittel). People wishing to contribute to the work of these groups should contact the discussion leaders.

Further information is available from Ugo Amaldi at CERN (on scientific matters) and Peter van Handel at DESY (on organizational matters). The Study will be followed by a meeting of the ECFA LEP Working Group as mentioned on page 19.

Pi in the sky

Following in the tradition of CERN memory man Wim Klein, Hans Eberstark (from the International Labour Organization in Geneva) featured in several recent attempts at CERN to smash the world record for recalling the number pi to as many decimal places as possible. A first attempt was unsuccessful as Eberstark inadvertently wrote down the 4 782nd and 4 783rd digits in the wrong order. A subsequent attempt used a different method to eliminate such random errors, and the number was revealed down to a mind-boggling 9 744 figures, easily surpassing the old record of a mere 5 050.

CERN 25th Anniversary Celebrations

On 29 September 1954 sufficient European Governments had ratified the Convention establishing the European Organization for Nuclear Research for CERN to come formally into being. To celebrate its 25th Anniversary, a ceremony will be held at CERN on 23 June immediately following the mid-year Council Session. Several other events and exhibitions, presenting CERN, its work and its future will be organized during the year. The COURIER itself plans to have a special CERN issue in September.

With this issue, CERN COURIER breaks with tradition by using a cover-date corresponding to the month in which it is distributed rather than the previous month, when the issue was prepared. No matter what date appears on the cover, the COURIER will continue to try to bring readers the latest news on the high energy physics scene worldwide.

Finally, we would like to thank Cherix et Filanosa S.A., printers of the CERN COURIER for the past two years, and whose skill and understanding has been of considerable help in the production of the journal.

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Michigan State University invites applications for the position of Associate Director for Administration in its Superconducting Cyclotron Laboratory. Appointee will handle internal administration of the Laboratory, coordination with federal agencies and coordination with other University units. Applicants should have five or more years experience as administrator/manager of major scientific project, preferably an accelerator project and demonstrated effectiveness in administering large federally sponsored programs.

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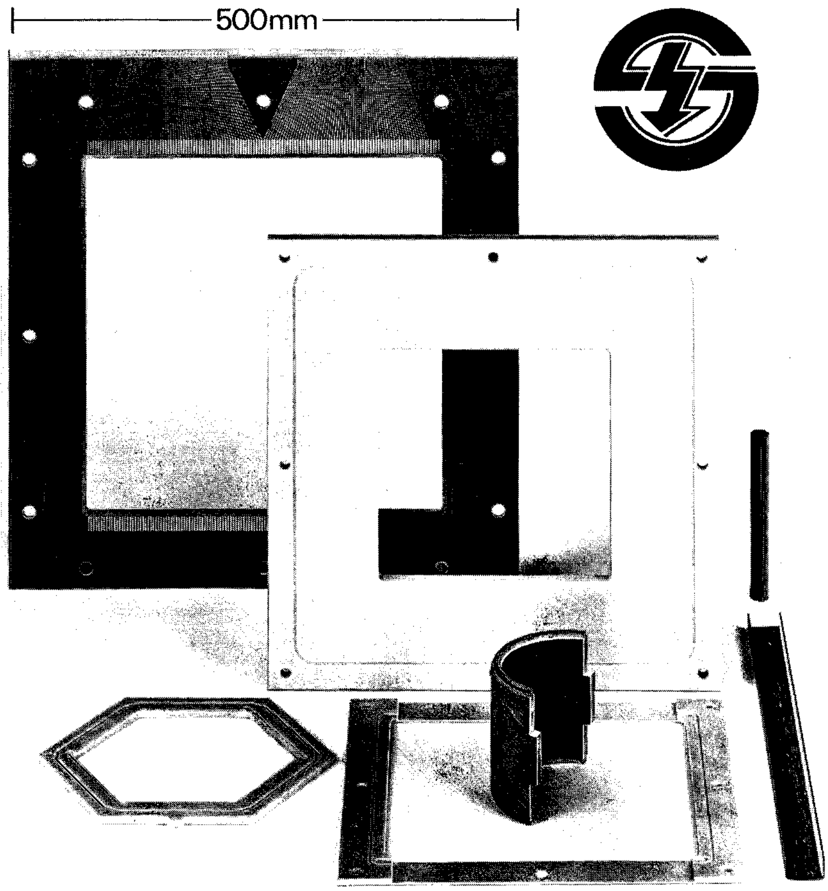

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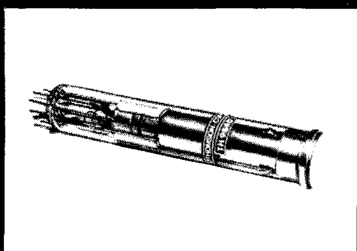

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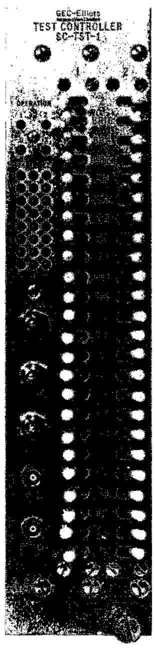

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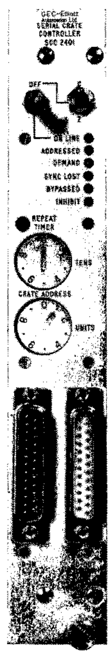
We also offer microprocessor-based crate controllers (both LSI-11 and Intel 8085) with memory, floppy disc, etc., software, configurations, test equipment, peripheral drivers and so on. We represent Hytec (UK) and Standard Engineering (USA) for the whole of their Camac equipment, including microprocessors, modules and full and half-sized powered crates.

How may we help you? Please contact Bob Broomfield at Zwicky Machines (Geneva 42 36 50) or direct to us at

GEC-Elliott Process Automation Ltd
CAMAC Sales Dept

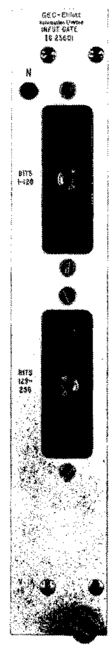
New Parks Leicester LE3 1UF England
Telephone: 0533 871331 Telex: 34551
a GEC-Marconi Process Control company

Autonomous Memory Channel for PDP-11 DMA at up to 2M Byte/sec



SCC 2401

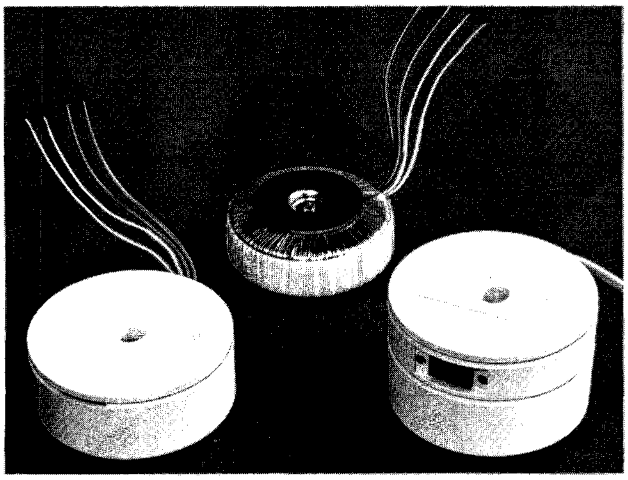
ADC 1232



IG 25601

Leitgeb importe aussi les meilleurs produits suédois!

Sélectionner dans le monde entier pour nos clients les meilleurs moyens de résoudre les problèmes techniques qui se posent à eux, c'est déjà devenu presque un hobby pour les ingénieurs de Leitgeb! Voici, par exemple, un des principaux produits de la société Transduktor Winding AB:



Le transformateur à tore

Eprouvé SEV

Le transformateur à tore

Avec tensions standards: 15–1000 voltampères. Sur demande, également livrable jusqu'à 10000 voltampères.

Pourquoi connaît-il un succès croissant?

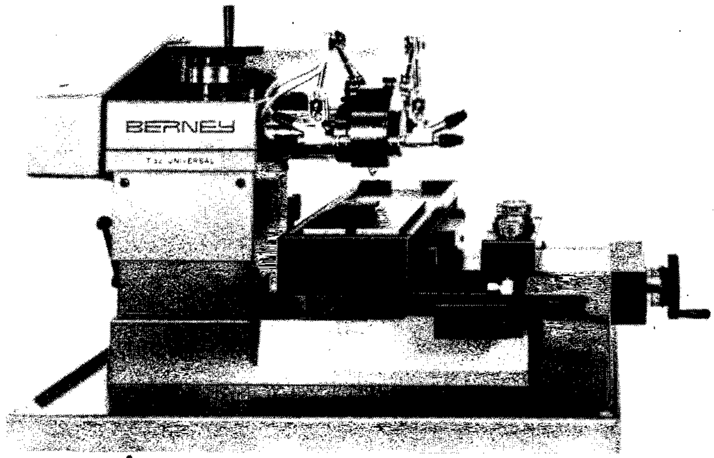
- poids minime
- volume restreint
- bruit de fond presque inexistant
- champ de dispersion réduit
- peu de pertes dues à la marche à vide
- montage simple

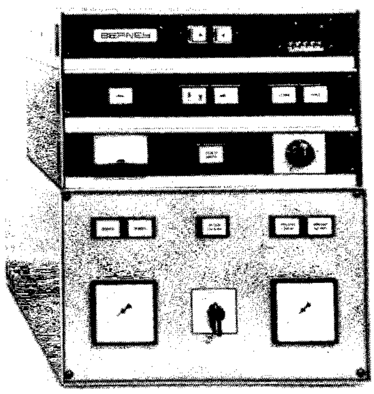
Et, avec tous ces avantages, il est à peine plus cher qu'un transformateur traditionnel. Faites un essai!

D. Leitgeb SA
8600 Dubendorf, Ueberlandstr. 199
Tél. 01/820 15 45, Télex 55 547

Ing. D. Leitgeb
A-9800 Spittal/Drau, Lagerstr. 51
Tél. 04762/4022, Télex 48 191

BERNEY T32 High Precision Saw





Modular and sturdy construction
Precise vibration-free spindle 0-20 000 rpm with electronic variator
Accuracy better than 0.01 mm (.0004")

- All kinds of Profiling, Cutting, Grinding and Once-Through Machining Processes in solid ALUMINE blocks and/or other extra-hard materials

BERNEY

Fabrique de Machines-Outils S.A.

CH-1341 Les Bioux (Switzerland)
Phone: (021) 85 61 29 Telex 22800 ronex

CAMAC

Introducing the 1st element of the most advanced CAMAC intelligent system:

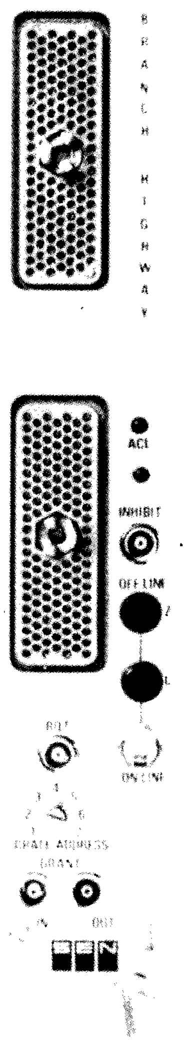
The SEN A2 Crate Controller
conforms to EUR 6500 specs. plus:
single board construction
fast clear input and SEN experience and support

DESCRIPTION

The A2 Crate Controller has been developed from the earlier A1 unit and has all the same functions plus new control logic for local data handling using a microprocessor. The A2 provides access to the N and L lines, via a rear panel connector, for an intelligent module placed in any normal station. It also handles the remote/local access request conflicts.

Front-end data processing is governed by this module just as long as the main computer does not require access to this particular crate: however, when this occurs, the local processor is released and its status saved. Subsequently the Branch demand is processed. Once the Branch demand has been filled, control returns to local processing.

«A2» CRATE CONTROLLER ACC 2089



SPECIFICATIONS

Front Panel

Crate Address	7 position switch allows selection of the addresses BCR 1 to 7 of the "A" Crate Controller.
ON LINE/OFF LINE	Links the Crate Controller to the Branch Driver.
Initialize (Z)	This push button sends Z signal in position OFF LINE.
Clear (C)	This push button sends C signal in position OFF LINE.
INHIBIT (1)	LEMO RA 00 C50 connector. Accepts 1 signal with TTL level.
Request (RQ)	Lemo RA 00 C50 Connector: Indicates RQ signal; TTL level
Grant IN (GI)	Lemo RA 00 C50 Connector: Accepts RQ signal output, or other signal according to the priority order; TTL level.
Grant OUT (GO)	Lemo RA 00 C50 Connector: Outputs GO signal (TTL) to the next Grant IN input.
ACL/RG LED.	LED indicating Request/Grant mode or Auxiliary Controller lockout (ACL) On when in ACL mode.

Rear Panel

LAM Grader Connector: 52 pin, double-density Cannon.
Auxiliary Controller BUS (ACB) Connector: 40 pin AMP.

PHYSICAL

Double width CAMAC module with shield covers on both sides. Fibre-glass printed circuit board with plate-through holes.
Meets electrical and mechanical requirements of EUR 4100e and 4600e.

POWER REQUIREMENTS

+ 6V	2.4A
– 6V	100 mA

Next month: The ultimate CAMAC microprocessor: ACC 2099 Auxilliary Crate Controller

France: ORTEC Sarl; 7, rue des Solets; Tel. (1) 687 2571 - Tlx 202553F, F-94 RUNGIS – **Germany: SEN ELEKTRONIK GmbH**; Brandstücken 11; Tel. 041 802046 - Tlx 2163705d, D-2000 HAMBURG 53 – **DIDAS Digital System**; Radspielstrasse 8; Tel. 089 916710 - Tlx 529167d - D-8000 MÜNCHEN 81 – **Switzerland: SEN ELECTRONIQUE SA**; CP 39; Tel. (022) 442940 - Tlx 23359ch - CH-1211 GENÈVE 13 – **SEN ELEKTRONIK AG**; Austrasse 4; Tel. (01) 9455103; Tlx 58257ch - CH-8604 VOLKETSWIL – **United Kingdom: SEN ELECTRONICS LTD**; London Street; Chertsey; Tel. 9328.66744 - GB - KT168AP SURREY – **OFFICES THROUGHOUT THE WORLD.**

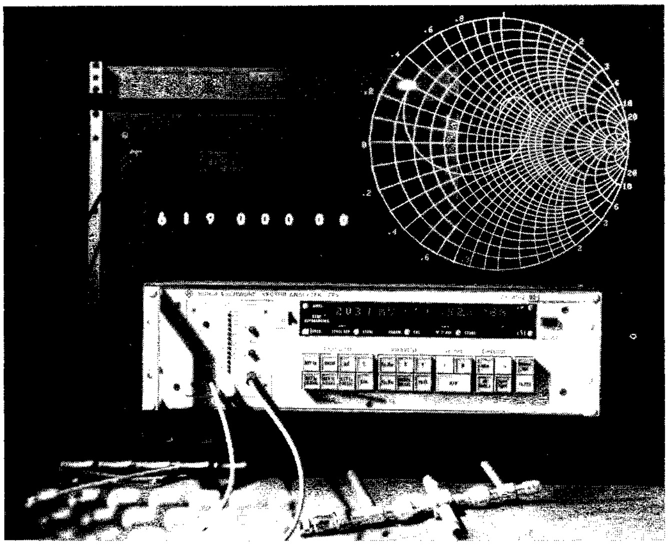
Headquarters:
SEN ELECTRONICS S.A.; Avenue Ernest-Pictet 31; Tel. (022) 442940 - Tlx 23359ch - CH-1211 GENÈVE 13.

SEN ELECTRONIQUE

ANALYSEUR VECTORIEL ZPV

ROHDE&SCHWARZ

0,1... 1000 MHz

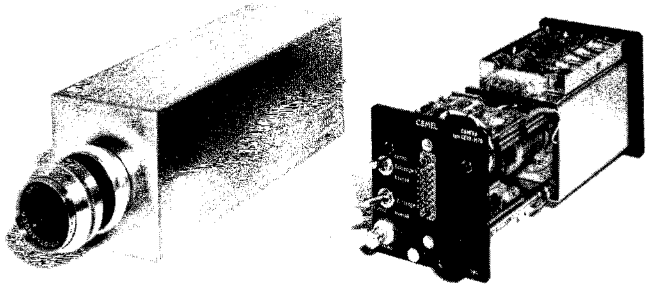


- Voltmètre vectoriel digital
- Indication directe des paramètres S et de l'impédance/admittance
- Sélection automatique des gammes
- Mesure du temps de propagation de groupe
- Compatible aux Bus IEC
- Système analyseur de circuit piloté par calculateur

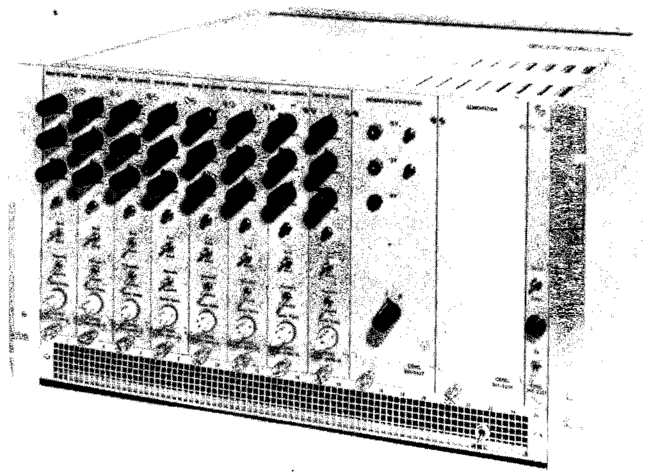
Représentation générale et service pour la Suisse

ROSCHI Télécommunication SA

3000 Berne 31, P.O.B. 63
Télex 32 137
Téléphone 031 44 27 11



CAMERA HEAD



CAMERA CRATE

RADIATION RESISTANT VIDEO CAMERA

RÉF: CERN (CH), SACLAY (FR), ORSAY (FR)

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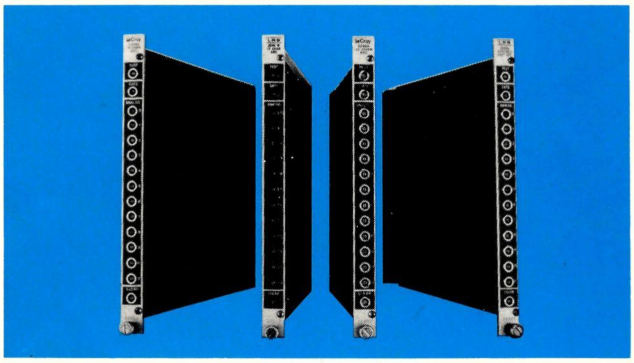
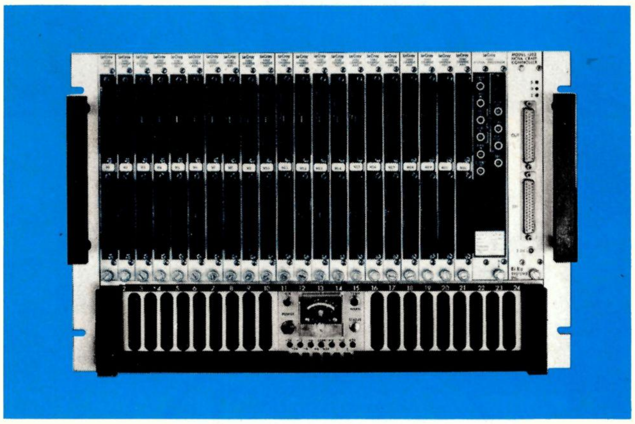
for ADCs look to LeCroy for the answer



MULTICHANNEL MODULES

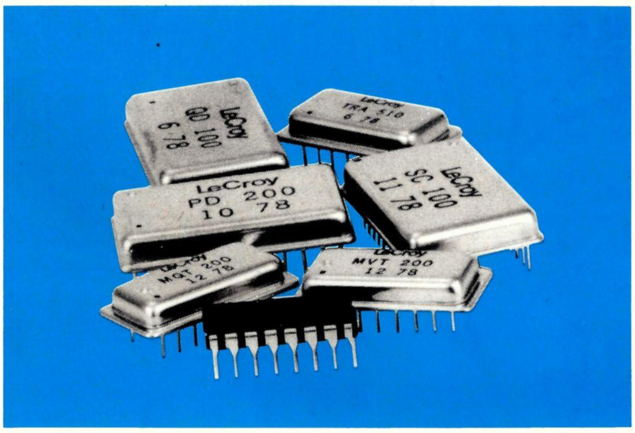
LeCroy,s twelve-channel CAMAC ADC's are the standard of performance in particle physics research. Their excellent linearity, dynamic range, stability, and reliability combined with their modularity make them ideal for the requirements and the size of today's experiments. For current-integrating applications Models 2249A and 2249W offer 10 and 11 bits respectively, while Model 2250Q offers 9 bits with rapid conversion and multiple buffered digital output. The 2259A is a peak-sensing model, offering 11-bit performance.



SYSTEMS

System 2280 fits the ADC needs of even the largest experiments with its unsurpassed density of 1008 channels per CAMAC crate. The Model 2280 system processor can automatically perform pedestal subtraction, data compacting, and other system functions. Software execution of these tasks is often impractical for large systems.

Custom monolithic technology produces exceptional accuracy and stability at low cost. For current-integrating applications Models 2282 and 2285 offer 12 bits, the latter featuring rapid conversion and readout. The 2283 features an unprecedented 15 bits! For peak-sensing applications the 2281 offers 12-bit performance even for 100 nsec input risetimes.



COMPONENTS

LeCroy's custom integrated circuits are ideal for special ADC applications requiring features otherwise unavailable. For example, LeCroy IC Models MQT200, and MVT200, front-ends for current-integrating and peak-sensing Wilkinson ADCs, incorporate temperature compensation, linear gating, a rundown current source, and a precision comparator on a single chip. These IC's simplify user design of high-sensitivity, high-accuracy instruments.

NEW SPECTROSCOPY ADC IN CAMAC

Model 3511—a significant improvement in ADC design—offers 8K resolution, 5 μsec conversion time, and better than 1% differential non-linearity.

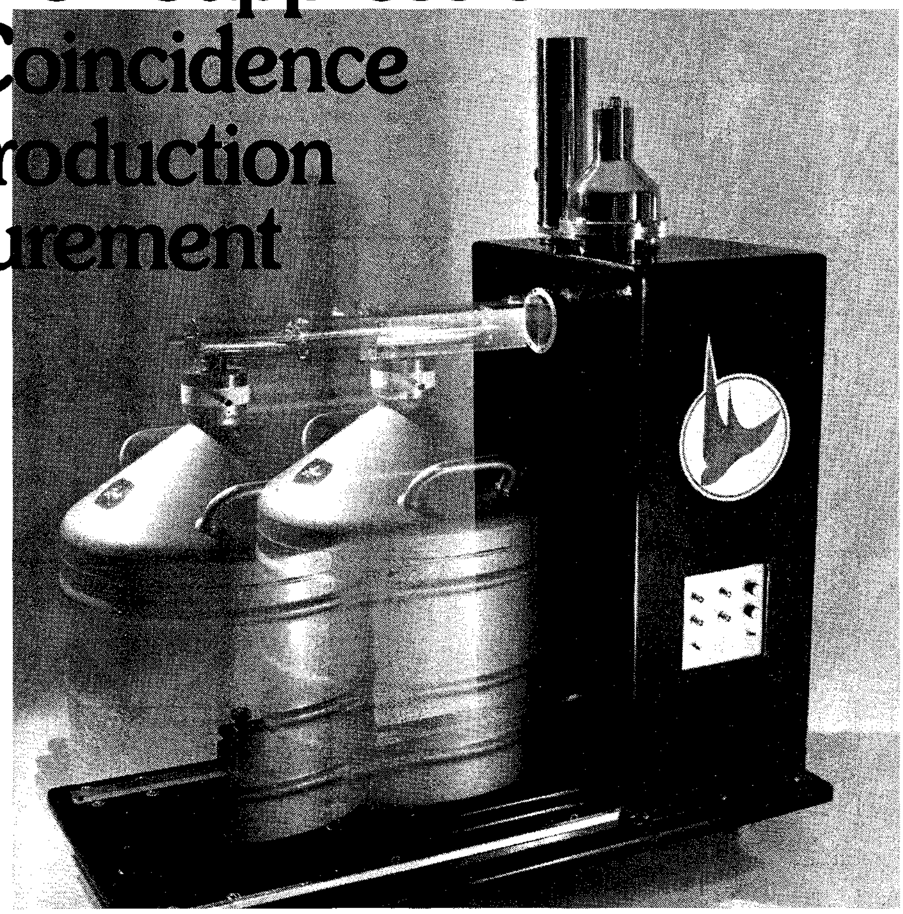
For further information, contact you nearest LeCroy office.

LeCroy RESEARCH SYSTEMS

Innovators in Instrumentation

Headquarters: 700 S. Main St., Spring Valley, N.Y. 10977. Offices: Chicago, (312) 626-6726; New England, (603) 483-8755; New York, (914) 425-0412; Palo Alto, (415) 328-6063; Geneva, Switzerland,41/22/98-93-41; Heidelberg, W. Germany, (06221) 28192; Hamburg, W. Germany, (040) 54 2713; Paris, France, 907.38.97; Wheatly, Oxford, England, (08677) 3540. Representatives throughout the world.

Bicron spans the equipment spectrum
•Compton Suppression
•Anti-Coincidence
•Pair Production Measurement

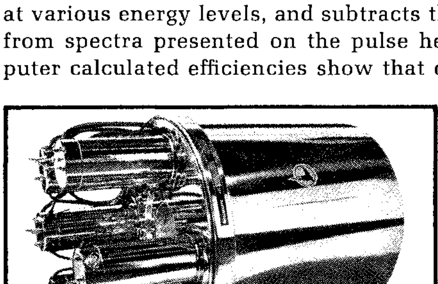


Bicron Model CS-1 Compton Suppressor.

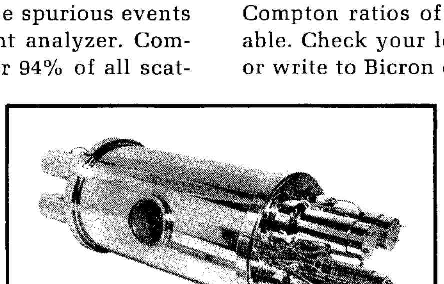
Bicron has addressed itself to the problem of enhancing the sensitivity of Ge(Li) spectrometers by developing NaI(Tl) crystal guard detectors to block Compton scattered events out of the spectrum. This equipment is now available in commercial form ready-to-use, or in major component form for those who wish to "customize" their own systems.

Enclosing of the spectrometer detector within the Bicron NaI(Tl) guard shield, discriminates Compton-related events at various energy levels, and subtracts these spurious events from spectra presented on the pulse height analyzer. Computer calculated efficiencies show that over 94% of all scattered gamma rays escaping the Ge(Li) detector are captured by guard crystals for sample emitted gamma rays up to 2 Mev. Efficiency is even higher at lower energy levels.

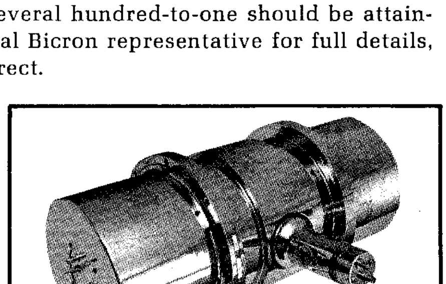
Peak-to-Compton ratio, and final sensitivity of the Ge(Li) spectrometer, is largely dependent on the characteristics and mounting of the detector. In a "worst case" configuration with a heavy 1.5mm thick dead layer, the ratio was approximately 150:1. With a properly specified detector, peak-to-Compton ratios of several hundred-to-one should be attainable. Check your local Bicron representative for full details, or write to Bicron direct.



Bicron Model 10HW10 (10" dia by 10" long NaI(Tl) crystal) with 3" dia center well. PHA resolution 10.2% for Cs^{137}.



Bicron Model 9HW5 (two 9" dia by 5" thick NaI(Tl) crystals coupled to two optically separated 9" dia by 4" thick pure NaI crystals). Composite resolution, summing all 8 PM tubes, 7.9% for Cs^{137}.



Bicron Model 9HSW9-X. 9" dia by 9" long NaI(Tl) crystals with 3" ID through center well. Crystal is split in center to form two 9" dia by 4½" long optically isolated detectors. Assembly pulse height resolution 7.4% for Cs^{137}.

BICRON CORPORATION 12345 Kinsman Rd., Newbury, OH 44065, (216) 564-2251