CERN COURIER

International Journal of High Energy Physics

VOLUME 23 10 DECEMBER 1983

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CERN COURIER is published ten times yearly in English and French editions. The views expressed in the Journal are not necessarily those of the CERN management.

Printed by: Presses Centrales S.A.
1002 Lausanne, Switzerland

Published by:
European Laboratory for Particle Physics
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 83 61 11, Telex 23 698
(CERN COURIER only Tel. (022) 83 41 03)
USA: Controlled Circulation
Postage paid at Batavia, Illinois

CERN COURIER

International Journal of the High Energy Physics Community

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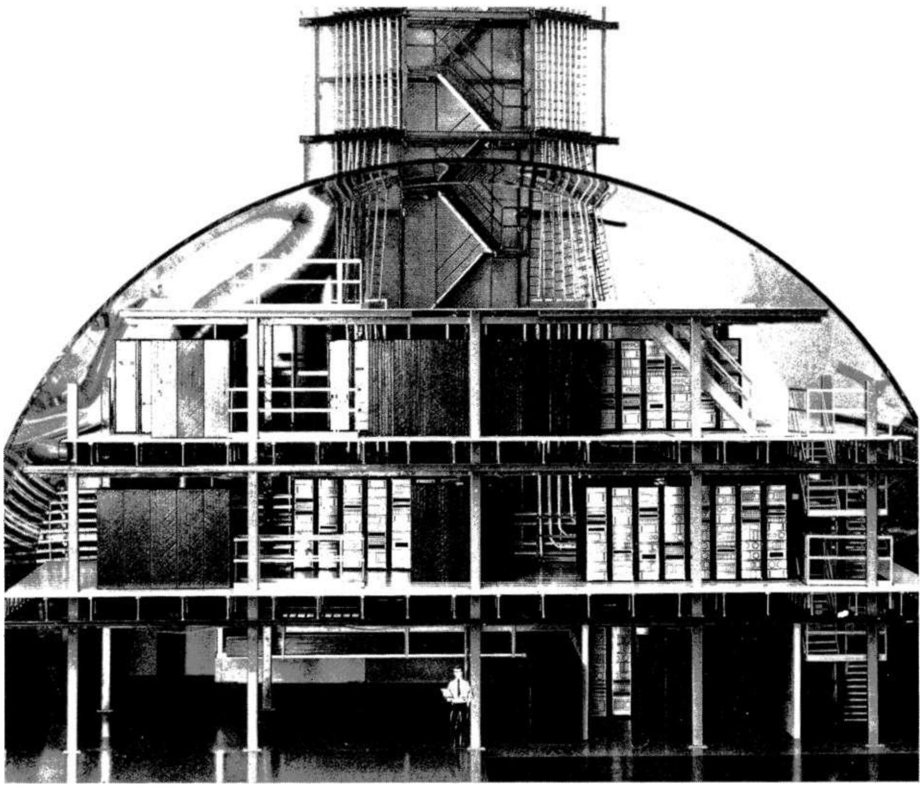
VOLUME 23 Nº 10 DECEMBER 1983

Cover photograph: DELPHI at Delphi. Tom Ypsilantis addresses some members of the 300-strong DELPHI (DEtector with Lepton, Photon and Hadron Identification) collaboration for an experiment at CERN's new LEP electron-positron ring. The collaboration meeting was convened at Delphi, near Mount Parnassus in Greece, the site of the most important temple of the god Apollo. Coming in the wake of the epic W and Z discoveries at CERN, this meeting provided a considerable stimulus to Greece's interest in CERN, and produced extensive press and media coverage.

Innovative instrumentation

Model of part of an underground area for an experiment at CERN's new LEP machine. With LEP now under construction, the requirements for new detection techniques are as intense as ever.

(Photo CERN 174.10.83)



At this year's particle physics conference at Brighton (see October issue, pages 303-11), a parallel session was given over to instrumentation and detector development. While this work is vital to the health of research and its continued progress, its share of prime international conference time is limited.

At Brighton, Bernard Hyams of CERN was given the task of picking out themes and highlights from the mass of contributed material. In his one-hour talk, he addressed himself to theoreticians and phenomenologists, assuming that instrumentation specialists would already be aware of most of what he had to say.

Instrumentation can be innovative three times — first when a new idea is outlined, secondly when it is shown to be feasible, and finally when it becomes productive in a real experiment, amassing useful data rather than operational experience. Hyams'examples showed that it can take a long time for a new idea to filter through these successive stages, if it ever makes it at all!

Track measurement

For measuring the tracks of charged particles, the main activity on the floor these days is with drift chambers. These are now well understood, but new developments, such as the vertex detectors for the Mark II experiment at SLAC's PEP ring and the TASSO experiment at DESY's PETRA ring, concentrate on improving the track resolution in the continuing hunt for short-lived particles.

The particles (tau meson, heavy flavours) now being sought have short lifetimes which test experimenters' ingenuity to the full. Using drift chambers, the precision is at best 100 microns and close tracks can be clearly distinguished only if their separation exceeds a few millimetres. This is barely sufficient for rare particle hunting.

Once the workhorse of particle detection, bubble chambers have been declared dead repeatedly. 'However they continue to expand,' declared Hyams. The tiny track lengths being sought in experiments (such as measurements of the charm lifetime) test conventional technology, and holography is now an attractive proposition. Small holographic bubble chambers are working, and large-scale applications for neutrino physics look possible (see October issue, page 317). Both BEBC at CERN and a 1 m chamber at Fermilab have achieved 50 micron bubble images.

Another holographic possibility has been pointed out by a Munich / CERN group, which has probed 60 micron distances using holograms in a tiny streamer chamber. This may have a future since streamer chambers, unlike bubble chambers, have already been used in colliding beam experiments.

Silicon strips were first used twenty years ago, but only recently has a particle physics experiment used the method in practice (see March 1982 issue, page 47). Charm lifetime measurements are now benefitting from this technique. With a spatial precision of some 5 microns and a track resolution of 100 microns, they offer a tenfold improvement over drift chambers, and work at higher rates.

Charged coupled devices have been developed for television cameras and other optical imaging applications. Applications for particle physics are being actively investigated (see June 1982 issue, page 179). Beam tests have shown a spatial accuracy of 5 microns and a resolution of 40 microns.

Other innovative tracking techniques being currently investigated (though not yet in production systems) include silicon drift chambers, and scintillating optical fibres.

Velocity measurement

Velocity measurements are important for particle identification. While conventional ionization instruments seem to be reaching their optimal performance, Ring Imaging Cherenkov counters (RICH), first proposed 25 years ago, are now emerging as a serious alternative. Several such counters have been built (Experiment 603 at Fermilab and a Serpukhov instrument described in the November issue, page 384). Their ability to distinguish between high energy pions and kaons is impressive.

Various methods are used to image the detecting rings, including wire chambers and Time Projection Chambers. One interesting development in the Cherenkov area is the approach taken by the mammoth underground Irvine / Michigan / Brookhaven experiment searching for proton decay and other rare events. This detector picks up its Cherenkov rings from a few thousand photomultipliers dangling in some 7000 tons of water, thus also providing tracking information.

Calorimetry

With the increasing complexity of the events being studied at high energy, particularly in colliding beam machines, better resolution of energy deposition (calorimetry) is required to pick up the large numbers of photons released in the decay of neutral pions, themselves copiously produced.

With this in mind, a high density projection chamber is being studied for the DELPHI experiment at CERN's new LEP machine. It is essentially a large Time Projection Chamber containing many concentric lead cylinders with narrow intervening gas volumes. Recent tests of the model have been encouraging, giving good energy resolution while pinpointing shower impact points to a few millimetres and separating showers as close together as 10 mm.

Other teams are looking at the relative merits of barium fluoride and bismuth germanate (BGO) for electromagnetic calorimetry. Barium fluoride is comparatively cheap but has longer radiation length. It scintillates in the ultra violet and this can be measured with a simple proportional chamber. BGO is expensive, but has shorter radiation length and holds the promise of a total absorption calorimeter with wire chamber readout giving high spatial resolution.

Computation

The last topic described by Hyams was computation. While interaction rates in electron-positron colliders pose no particular problems, the high luminosities in hadron machines (both fixed target and colliders) mean that some kind of pre-selection has to be made. Existing techniques can only record a few events per second. Even then each event can produce a prodigious amount of information, requiring some ten seconds of processing time on a modern mainframe machine. Data processing thus quickly becomes a bottleneck.

One solution being increasingly advocated in sectors with limited computer resources is the development of special processors tailor-made for the particular application. One such project by a collaboration at Fermilab aims to handle some 10^5 events per second, each event having about twenty tracks.

CERN
First results from LEAR

When new physics conditions are opened up, new results are not far behind. Earlier this year the physics experiments at the LEAR Low Energy Antiproton Ring had their first taste of antimatter (see October issue, page 314). LEAR enables physicists to explore in depth the interactions of antiprotons under conditions which could only be briefly glimpsed before.

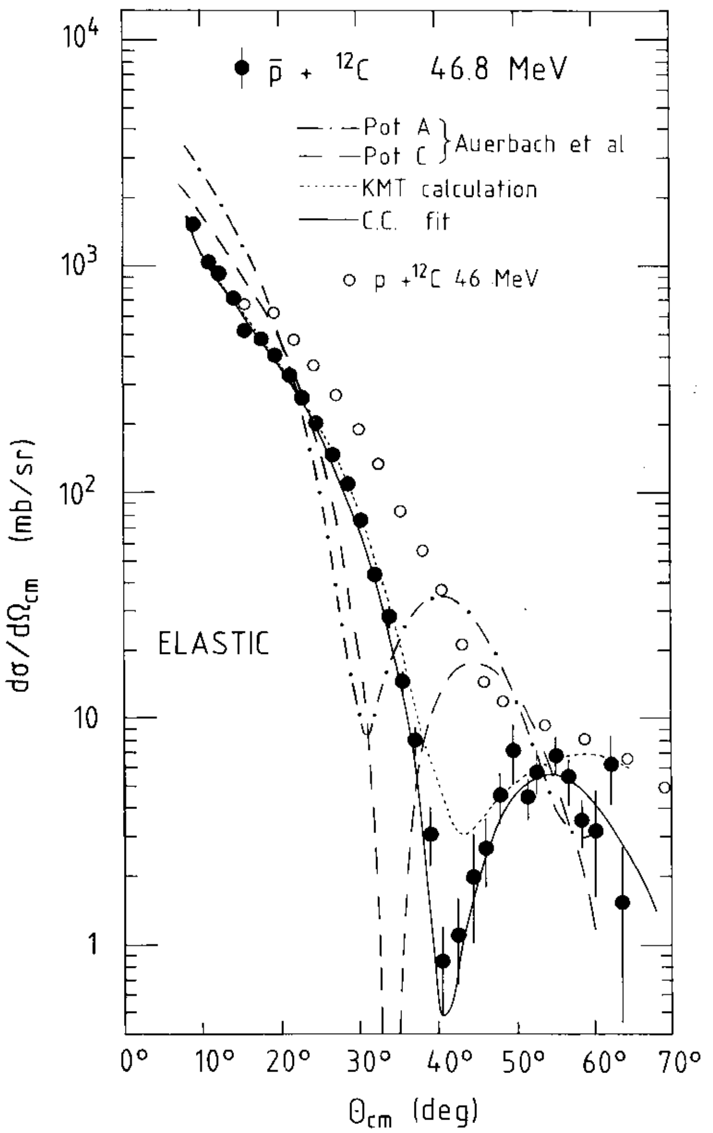
Using data from ten fifteen-minute spills of low energy antiprotons, giving a total of 3.5×10^8 antiprotons on target, a Saclay / Grenoble / Strasbourg / Tel Aviv collaboration has measured the scattering of 309.4 MeV/c momentum antiprotons off carbon nuclei.

This is the first step of a planned systematic study of antiproton-nucleus scattering, using a range of energies and target nuclei.

After scattering from the carbon target, the antiprotons were magnetically analysed by the SPES II spectrometer, allowing absolute elastic and inelastic reaction rates (cross-sections) to be determined. Data were taken at scattering angles from 10 to 55° in overlapping steps, and the apparatus was calibrated in initial runs with protons.

The elastic scattering angular distribution (where the antiproton appears to 'bounce' off the target nucleus) shows a diffraction-like pattern, in marked contrast to the elastic scattering of protons off carbon. Excitation spectra show the production rate of excited nuclear states, which also is different to that seen with protons.

These initial measurements put powerful constraints on the nature of the antiproton-nucleus interaction,



First physics results from the LEAR Low Energy Antiproton Ring at CERN. The elastic scattering of antiprotons from carbon nuclei (black data points) shows a pronounced diffraction-like pattern.

previously almost unknown. Already these eliminate some of the theoretical pictures which have been proposed. Compared to similar proton experiments, the continuum part of the scattered spectrum is strongly suppressed, tending to support earlier speculation that multiple scattering of antiprotons is relatively improbable.

These are the first tentative steps in an interesting programme which should provide useful information on both nuclear properties and nucleon-antinucleon interactions. In addition, other LEAR experiments should soon yield results which should help provide additional new insights into both hadronic and nuclear force mechanisms.

Charmonium from antiprotons

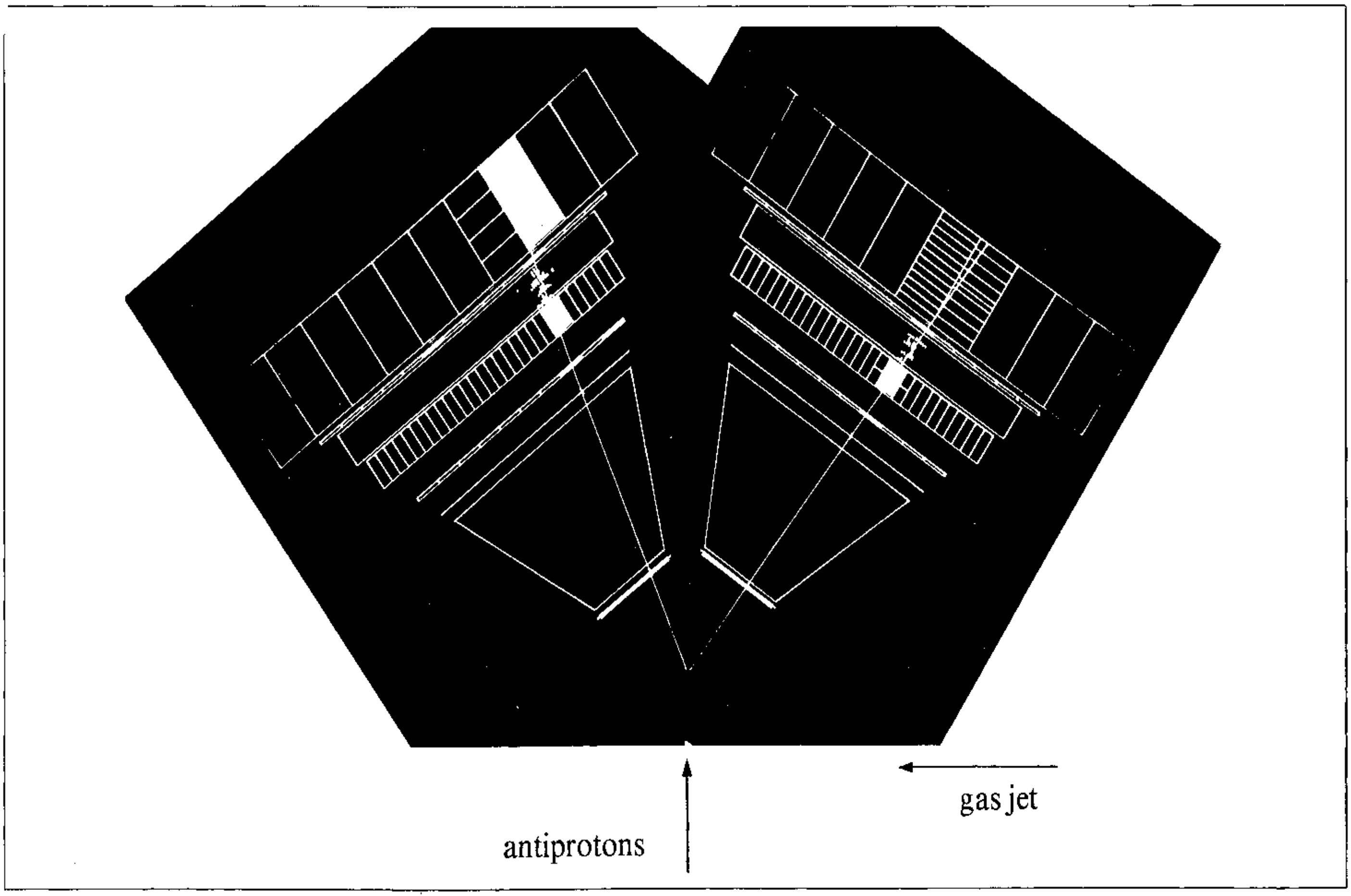
Some of the final contributions to physics from the Intersecting Storage Rings (ISR) will come from an Annecy / CERN / Genoa / Lyon / Oslo / Rome / Turin team studying the charmonium states created when a circulating antiproton beam hits protons in a hydrogen gas target.

Charmonium, the bound states of charmed quarks and their antiquarks, has largely been the province of experiments at electron-positron rings. However the creation of charmonium under these conditions is restrictive, as only certain states can be formed directly. Others have to be searched for in subsequent decay modes, and data is difficult to come by.

The creation of charmonium in proton-antiproton annihilation is much less restrictive, and all states can be formed directly. In this way the ISR experiment hopes to extend our knowledge of charmed quark spectroscopy, and hence our understanding of quark behaviour.

For this experiment, the ISR is operated in a novel mode, with antiprotons circulating in one ring, but with no particles in the other. The antiprotons from the Antiproton Accumulator are ejected towards the PS in the standard way, and sent on to the ISR after less than a turn in the PS.

Once the low energy antiprotons are in the ISR, the first step is to cool them and accelerate them to the beam momentum of 4.066 GeV — the value needed to hit the famous J/psi resonance. This is recognized by its decay into electron-positron pairs. Four short runs gave about 70 J/psis, showing that the technique worked, and enabling the detectors to be checked out.



To hit a resonance spot-on, the antiproton beam can either be accelerated using the r.f. phase displacement method, or can be adjusted smoothly (but more slowly) using the momentum cooling system. With 3 mA of circulating antiprotons and a design figure target density of 6×10^{13} atoms/cm^2, proton-antiproton collision luminosity was 1.5×10^{30} cm^{-2} s^{-1}.

After initial success with the J/psi, attention turned to other particles. The J/psi and heavier counterparts consist of a charmed quark and antiquark bound together with their spins parallel, but carrying no relative angular momentum. Other particles (chis) have a similar quark spin configuration, but carry one unit of orbital angular momentum. They are recognized by their decays into electron-positron pairs (from J/psis) plus a gamma ray. Also possible are the 'singlet' charmonium states with opposed quark spins (like the eta-c) which can decay into pairs of gamma rays.

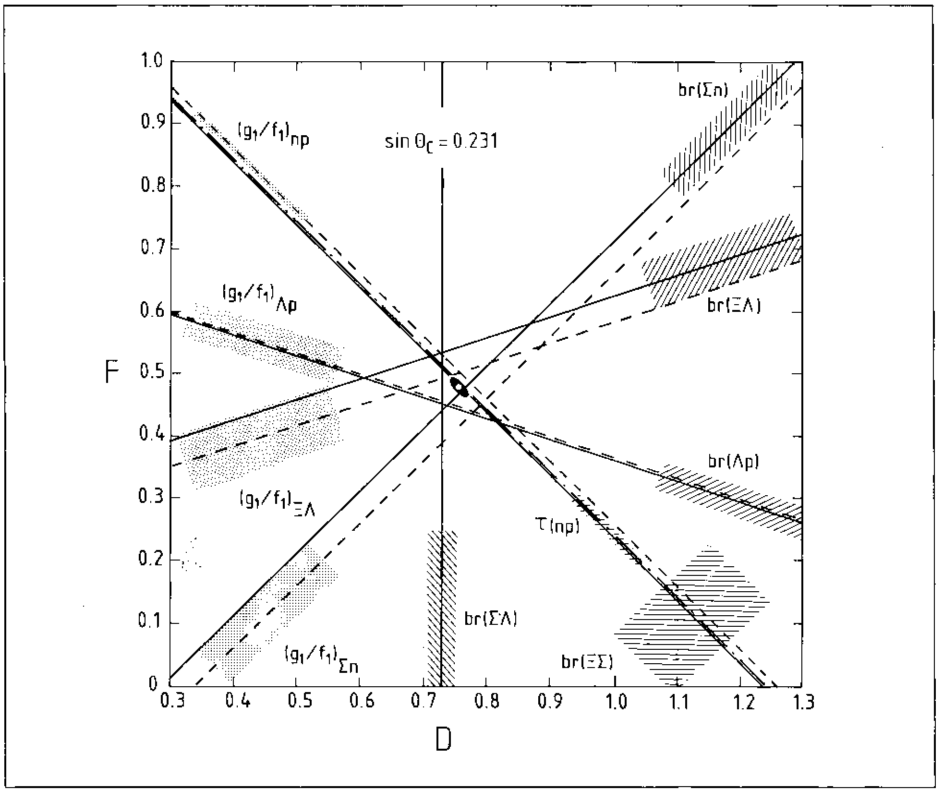
Detection of a J/psi (decaying into an electron-positron pair) in the experiment at the CERN Intersecting Storage Rings (ISR) using a stored antiproton beam incident on a hydrogen gas jet target. For this experiment only one of the ISR rings is used.

In the initial data samples, the production of chis appears to be a bit lower than expected, but it is too early to draw firm conclusions. Additional data from runs next year will shed further light on these states. The high 'tunability' of the machine might enable other narrow states to be encountered. There has been talk recently of candidate Higgs particles lying in the region. The systematic energy sweeps available from the ISR should enable a thorough search to be made, providing a fitting conclusion to the physics career of this wonderful machine.

Well behaved hyperons

In her review talk on weak decays at the Brighton Conference, Cecilia Jarlskog paid tribute to the excellent work of the Bristol/Geneva/Heidelberg / Orsay / Rutherford / Strasbourg collaboration's experiment at CERN (WA2). This thorough high statistics study of the weak semileptonic decays of heavy baryons (hyperons) has produced decisive results.

Each hyperon type corresponds to a different mixture of quarks and within the accepted SU3 classification of particles, their semi-leptonic decays can be described according to an elegant model proposed by Nicola Cabibbo in 1963 with only three parameters: the Cabibbo angle θ_c and two 'transition elements' F and D. At the time only three quark flavours were known, but the ideas



Hyperon semi-leptonic decays in good shape. Apart from the case of free neutron decay (n p) all the data come from the WA2 experiment at CERN. According to the Cabibbo theory, the lines should intersect at one point. The centre of the small black ellipse is the best estimate of the common point of intersection of the lines, and the size of the ellipse indicates the experimental uncertainties. This is the best evidence so far for the correctness of the Cabibbo model, applied to so many different particle systems. The shaded bands represent experimental errors.

have been extended to cover the conventional six-quark picture of today.

A major problem in previous tests of the Cabibbo model had been the necessity to combine data from many different experiments analysed under a variety of assumptions which were liable to produce inconsistent results. The objective of the WA2 experiment was to make a coherent, comprehensive and precise study of the various hyperon semi-leptonic decays measured in a single apparatus, and to see how the results compared with the Cabibbo model.

One of the unique features of the initial experimental programme at the CERN SPS super proton synchrotron when it began operations in 1976 was its high energy charged hyperon beam. A magnetic channel, short so as to minimize the hyperon decay losses, selected 100 GeV charged particles produced in the forward direction by the interaction of the 210 GeV SPS proton beam on a target. A 'DISC' Cherenkov counter identified different kinds of hyperons (sigmas and ksis), about four per thousand charged beam particles. Wire chambers on either side of the DISC particle identifier accurately measured the directions of the particles enabling their momenta to be measured to within one per cent.

Downstream of the DISC was a 10-metre long helium-filled decay region, followed by a magnetic spectrometer which measured the charged particles emitted in the hyperon decays. An impressive arsenal of detectors, including a lead-glass array, a gas Cherenkov counter, transition radiation detectors and a lead scintillator shower counter identified electrons. Together these detectors provided excellent discrimination against the much more copious non-leptonic hyperon decays.

The WA2 experiment has looked at an extensive list of semi-leptonic decays of ksi, sigma and lambda hyperons. For several of the decays considered, precision reached the level at which radiative effects due to emission and absorption of photons had to be taken into account.

For each semi-leptonic decay the rate and the decay distributions give independent relations between the three parameters F, D and sin θ_c. Powerful additional constraints on the parameters of the model come from experiments on free neutron decay. The results from the WA2 experiment, whether considered alone or with the addition of the neutron decay constraints, are in complete accord with the Cabibbo model.

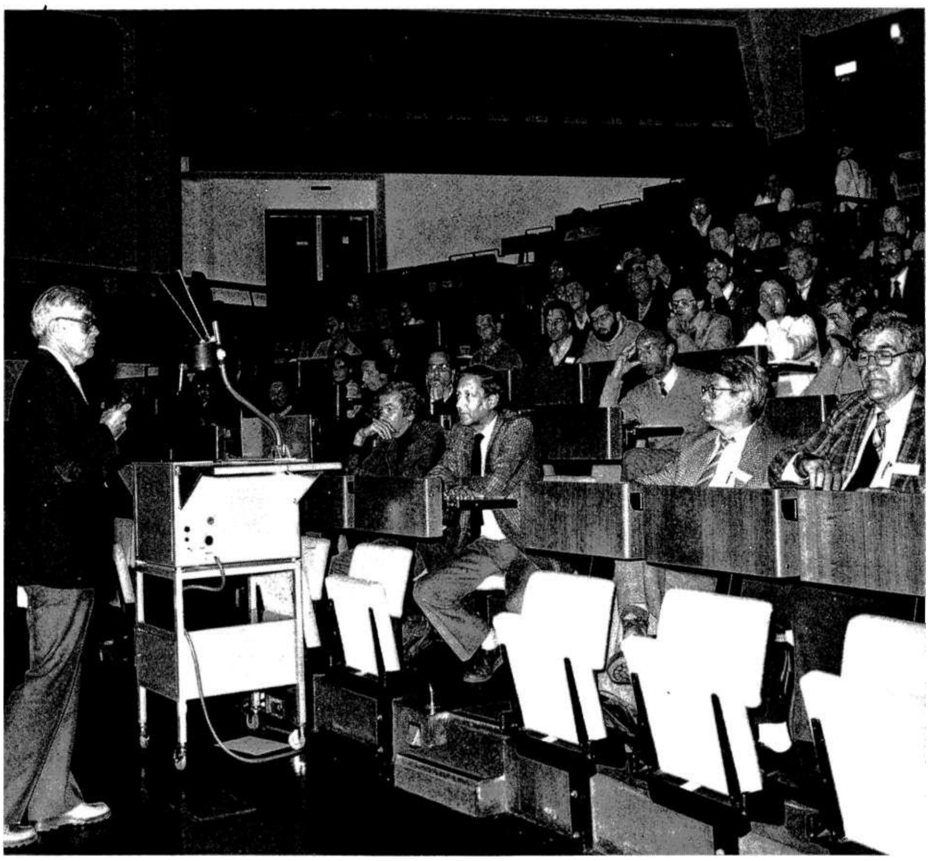
Accelerator School successfully launched

The first course of the newly created CERN Accelerator School under the leadership of Kjell Johnsen was held at CERN from 11-21 October. Its subject, 'Antiprotons for Colliding Beam Facilities', was selected obviously in the light of the recent spectacular achievements in this field. The School will be back-tracking in its next planned course in September 1984 with a basic course on accelerator physics accessible to post-university science and engineering students.

The School has several aims in the general context of broadening the base of accelerator physics knowledge in Europe. There is need to attract young people into this field, particularly with the tremendous challenge of mastering new acceleration techniques so as to be able to continue the advance of high energy physics into the next century. In addition, accelerator physics has increas-

Kjell Johnsen, leader of the newly created CERN Accelerator School, introduces one of the sessions in the recent course on 'Antiprotons for Colliding Beam Facilities', held at CERN.

(Photo CERN 400.10.1983)



ing application in other fields (for example the uses of synchrotron radiation sources and spallation neutron sources in a wide variety of research, plus all the potential applications in medicine, inertial fusion, radio-isotope dating etc.). It is one of the responsibilities of the established accelerator centres to ensure a thriving community of accelerator experts to respond to all these needs in the future.

The first schools of this type took place in 1976 at Erice, led by Kjell Johnsen and later in the USA at Fermilab, Stanford and Brookhaven led by Mel Month. The CERN Accelerator School series got off to a flying start with the antiproton course which was excellently organized, particularly by Phil Bryant. There were over a hundred participants, including some from the USA. All the lectures were exceptionally well prepared and covered their topics from the basic ideas to the present frontier of our understanding.

Simon van der Meer who conceived the stochastic cooling technique even pushed that frontier further out when he presented some new approaches during the discussion session on stochastic cooling which he chaired. There were also new ideas presented about the possibilities of cooling very high energy beams (such as the stored beams of around 300 GeV in the SPS) which was considered as an intractable problem until recently. There was also the first presentation by Bruno Autin of the complete antiproton collector, ACOL, proposal which has just been published. This is designed to step up the CERN proton-antiproton collider luminosity significantly.

Many other topics deserve mention, such as the report by John Peoples, an invited speaker, on the Fermilab Tevatron project which will eventually overtake the abilities of the CERN collider, the resurgence of physics with gas jet targets, other potential applications of cooling techniques in heavy ion machines, free electron laser systems etc. ...but with this issue following close on the heels of our special issue on the W, Z discoveries last month we are wary of irradiating readers with too high a flux of antiprotons. The significant news is that the CERN Accelerator School is off to a very healthy start which bodes well for the realization of its aims over the years to come.

CERN/FRASCATI
Searching for gravity waves

With the discovery at CERN earlier this year of the W and Z bosons which carry the weak nuclear force, the list of the different types of 'radiation' which transmit the forces of Nature is almost complete. Only the carrier of the gravitational force now needs to be found.

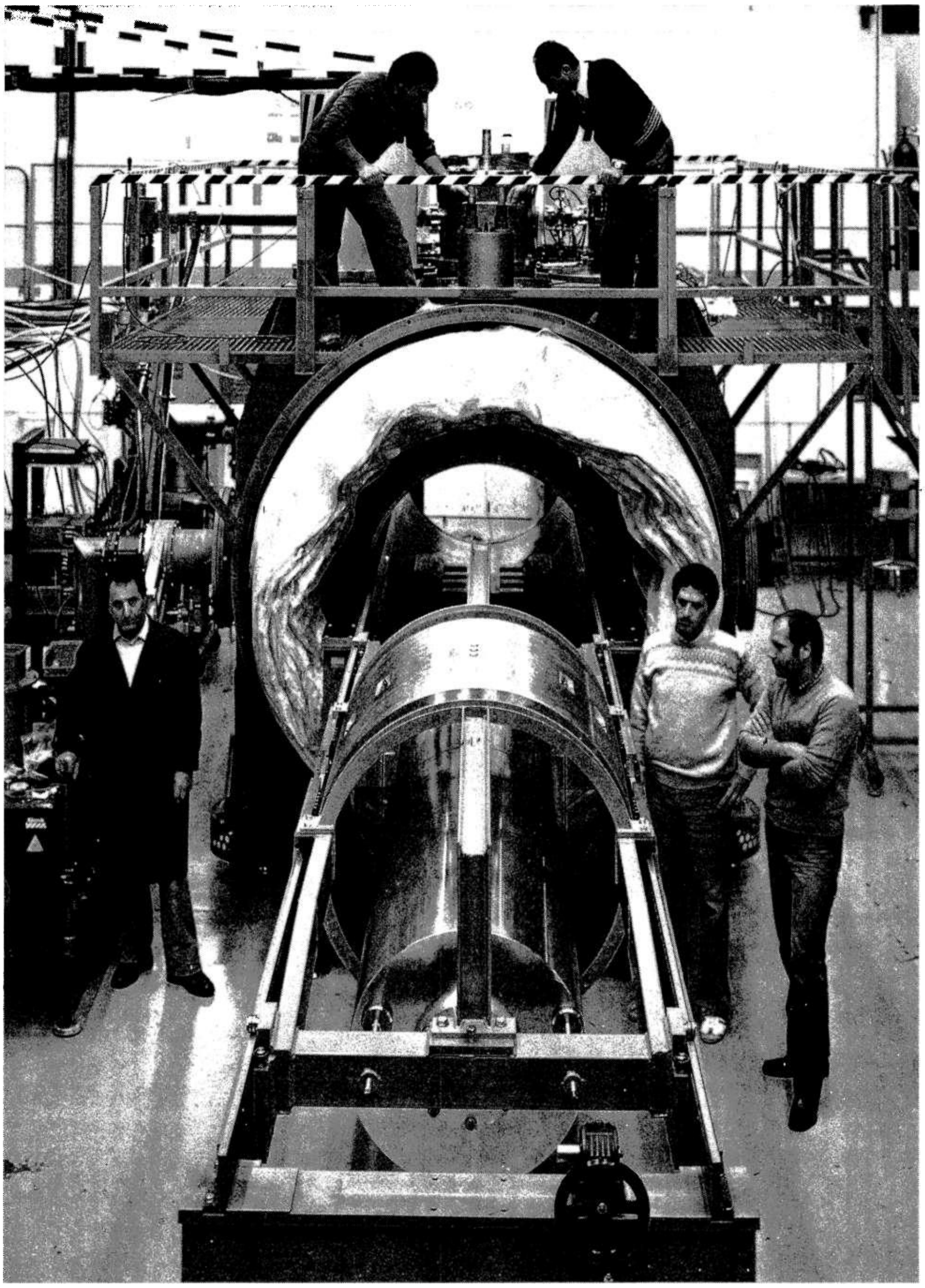
Gravitational radiation, predicted by Einstein's general theory of relativity, should consist of ripples of geometry which shake objects in their path. Due to the extreme feebleness of this force on an everyday scale, these effects would be tiny. The oscillation of even a quite substantial detector exposed to gravitational radiation would be smaller than an atomic nucleus!

A few years ago, a 400 kg gravitational antenna came into action at Frascati. To minimize thermal noise, the detector is cryogenic. Oscillations of the bar were monitored and an 'event' was deemed to occur when the signal exceeded a threshold value.

These discontinuous readings were converted into a spectrum by Fourier analysis, and the results from measurements carried out in 1978

The new 2.3 ton cryogenic gravitational wave antenna of the Rome group at CERN, now being tested.

(Photo CERN 25.10.1983)



and 1980 showed that these events, corresponding to sub-microscopic mechanical vibrations in the antenna of the order of 2 x 10^{-15} m, tend to occur with a regular period of one half of the sidereal (astronomical) day – 718 minutes.

It is exceedingly improbable that this result is due to a statistical quirk. With gravitational waves ruled out, explanations favour earth movements which excite the antenna. But there is no explanation for the regularity of the signal.

To check this initial result, a big (2300 kg) detector at CERN (see October 1982 issue, page 323) came into action. Unlike the Frascati antenna, this detector operates at room temperature. The results from 2500 hours of measurement confirm the earlier findings.

The characteristics of the two detectors are very different, and in addition the CERN results are not changed if the orientation of the detector is turned through a right angle. Because of this intriguing result, new measurements are necessary. These are scheduled for the coming months. In addition, a new 2.3 ton cryogenic antenna is being tested at CERN.

Whatever the explanation for this new effect, the search for gravitational waves continues undeterred.

CERN/USSR
Heavy neutrals

Under the CERN/USSR agreement on collaboration in particle physics, an experiment at CERN and another at Serpukhov are looking for heavy neutral particles which decay into gamma rays.

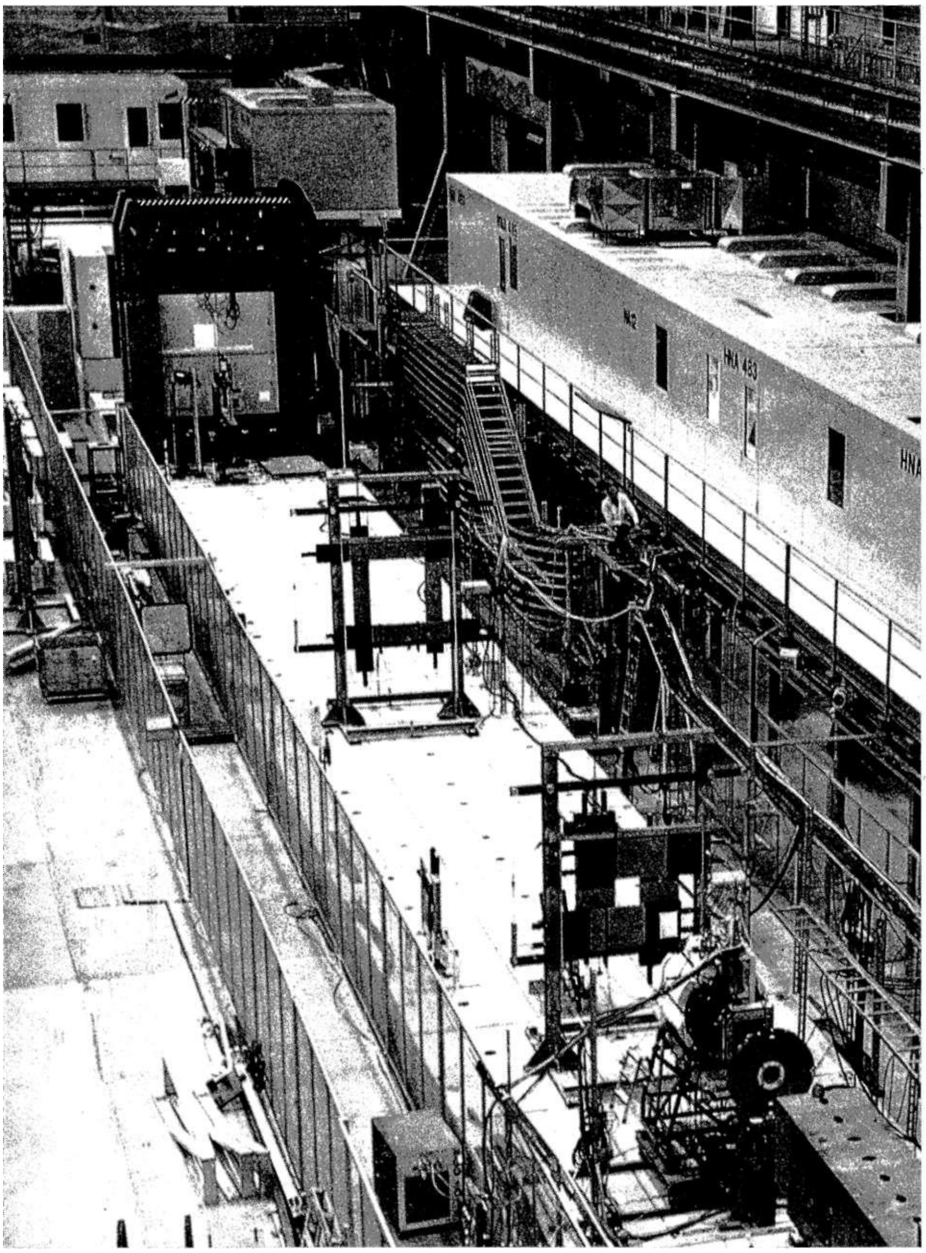
These studies complement the results coming from experiments at electron-positron storage rings and provide new spectroscopy information in an area of great potential interest for particle physics.

The experiment involves parallel studies at the 70 GeV Serpukhov proton synchrotron (sixth joint Serpukhov Institute for High Energy Physics/CERN experiment) and at the 450 GeV CERN SPS Super Proton Synchrotron (NA12 experiment). The physicists come from Serpukhov, Brussels and Annecy. The central feature of each set-up is a large Cherenkov lead-glass hodoscope spectrometer which measures the momentum and direction of emerging gamma rays. These instruments have earned the Russian acronym GAMS.

One of the recent results from the sixth joint experiment at Serpukhov comes from the detailed analysis of 38 GeV negative pion-proton collisions producing two neutral pions, decaying in turn into four gamma rays.

Top left, the GAMS detector of the CERN/USSR experiment (NA 12) at the CERN SPS 450 GeV Super Proton Synchrotron. Its 4096 precision-built lead-glass cells pick up photons from the decay of heavy neutral particles produced in the target (bottom right).

(Photo CERN 71.4.82)



This has revealed a neutral meson carrying spin (intrinsic angular momentum) of six units, the highest integer spin particle ever found, at a mass of 2510 MeV. It looks to be a higher angular momentum partner (Regge recurrence) of the spin 4 h-meson and the spin 2 f-meson.

Initial evidence for the spin six state came in the mass spectrum of the two neutral pions, and further angular momentum analysis showed that a spin six particle is required to produce the observed effects.

Another analysis of the data from the same experiment concentrates on events producing pairs of eta mesons. This is of special interest in the search for exotic new states, such as 'gluonium' ('glueballs') — particles containing only gluons and no quarks.

Preliminary analysis of the mass distribution of the decay products coming from two etas showed something happening at around 1350 MeV. Detailed analysis of the observed angular distributions showed that this was the f meson (spin 2) previously seen in a variety of interactions, however data on its decay into two etas had been scanty.

Subsequent analysis also uncovered a signal at 1590 GeV, identified as a scalar (spin zero, positive parity) meson. This is not seen in the analysis of two neutral pions, and is also apparently reluctant to decay into two kaons. This quark-shy state joins a list of glueball candidates seen in other reactions.

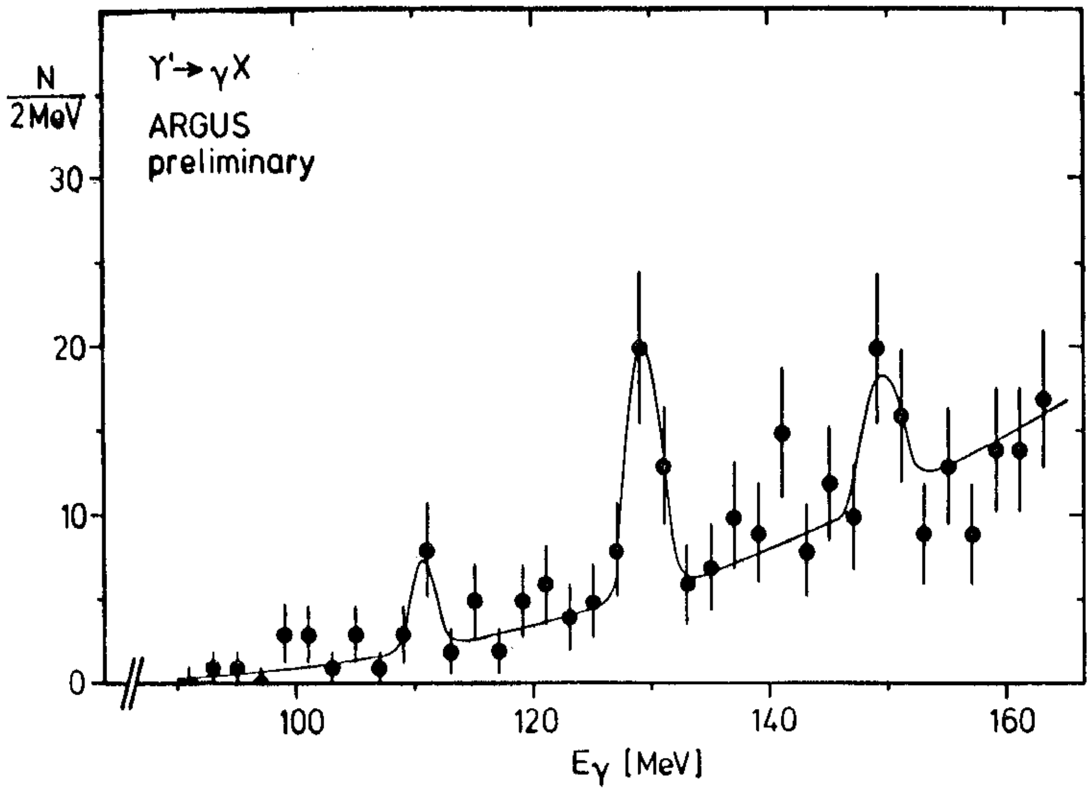
Further information on particle spectroscopy from the analysis of eta pairs will also come from the sister NA 12 experiment still taking data at the CERN SPS.

DESY
ARGUS drifts in

The ARGUS detector at DESY's DORIS-II electron-positron ring continues to provide some good results on particle spectroscopy. The June issue (page 185) reported an example of the decay of an upsilon prime particle through an intermediate b quark-antiquark bound state carrying one unit of angular momentum (P-state). In this event, one of the emitted photons was converted in the beam-pipe into an electron-positron pair, and could thus be measured very accurately.

Since then, the ARGUS group has collected more than 70 such events, and a preliminary photon energy distribution confirms the findings of the CUSB group at Cornell's CESR ring looking at P-state upsilons. As well as carrying one unit of angular momentum, these states also have parallel quark spins (triplet states).

Energy spectrum of photons coming from the decays of upsilon prime resonances. The energy measurement was made for photons converted into electron-positron pairs in the beam pipe or inner wall of the ARGUS detector at DESY.



Triplet P-state	ARGUS	CUSB
	Photon energies	
$^3P_2$	111.4 ± 2.0 MeV	108.2 ± 0.3 MeV
$^3P_1$	129.5 ± 0.6 MeV	128.1 ± 0.4 MeV
$^3P_0$	148.5 ± 2.1 MeV	149.4 ± 0.7 MeV

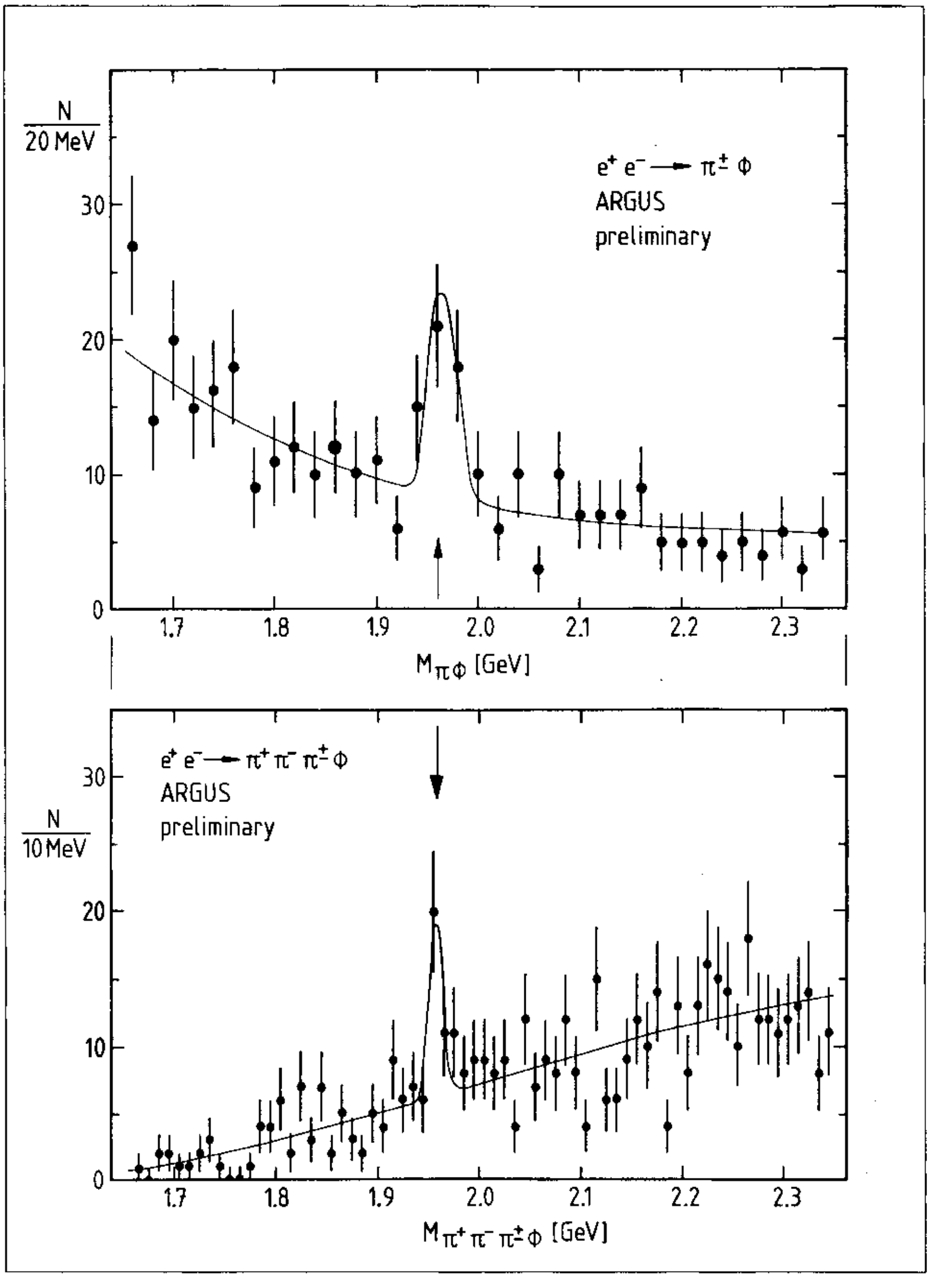
Data on this upsilon family decay chain is now quite precise. In addition, there has been an absolute measurement of the upsilon prime mass by the DORIS-II Accelerator Group in collaboration with both the ARGUS and Crystal Ball experimental groups working at the ring. This result was presented at the Cornell Lepton/Photon Symposium in August. It used the depolarization method (see July/August issue, page 224). At the upsilon prime energy, the DORIS-II beams are about 80 per cent polarized. The upsilon prime mass obtained is 10023.1 ± 0.4 ± 0.5 MeV.

An earlier measurement using a similar technique at Novosibirsk gave the mass of the ground state (S, triplet) upsilon as 9459.7 ± 0.7 MeV (see October 1982 issue, page 325). Thus the mass difference between the ground state upsilon and its first excited state (upsilon prime) is thus 563.4 ± 0.9 MeV. Using the ARGUS and CUSB measurements of photon energies resulting from upsilon decay, preliminary values for the P-upsilon masses can now be obtained.

The ARGUS team is also investigating other events, making use of their exceptionally accurate drift chamber. Energy loss of charged particles is measured with a precision of 4.1 per cent and transverse momenta with 1.2 per cent accuracy at 1 GeV. This enables protons, kaons, pions and electrons to be distinguished over wide ranges of momentum.

This yielded a signal for the elusive F meson, carrying charm and strangeness. The F mesons were identified through their decay into a phi meson and one or three charged pions. A remarkably clear phi signal was obtained by picking up (through energy loss measurements) the charged kaon pair into which the phi decays. The preliminary value for the F mass is 1970 ± 10 MeV, in good agreement with the result announced earlier this year by the CLEO team working at Cornell, and lower than earlier measurements of the F mass which are now in the scientific literature. These results were ob-

Evidence for the F meson (carrying charm and strangeness) decaying into a phi mes plus one or three pions, as seen in the ARGUS detector at DESY's DORIS-II ring. The mass agrees with a measurement earlier this year by the CLEO group at the Cornell CESR ring. Both are lower than earlier measurements.



tained from 25 inverse picobarns of total luminosity collected at DORIS-II, with energies in the upsilon and upsilon prime regions and the neighbouring continuum.

These results, and others expected soon, are in a large part due to the ARGUS drift chamber. This uses 172 cm diameter cylinder with 15 cm radius left free around the axis for the beam-pipe and for a vertex chamber which is being brought into operation. The length of the drift chamber wires is 200 cm. All the volume is filled uniformly with 5940 drift cells of 18 x 18.8 mm, giving 36 layers, 18 of which are slighlty tilted to obtain stereo views.

The chamber is filled with propane with 3 per cent of methylal to avoid aging, at a pressure of one atmosphere. Multiple scattering is therefore kept very low. Combined with thin wires (only 76 microns for the high voltage, wires and 30 microns for the sense wires) the material inside the chamber amounts to an equivalent of only .0055 of a radiation length.

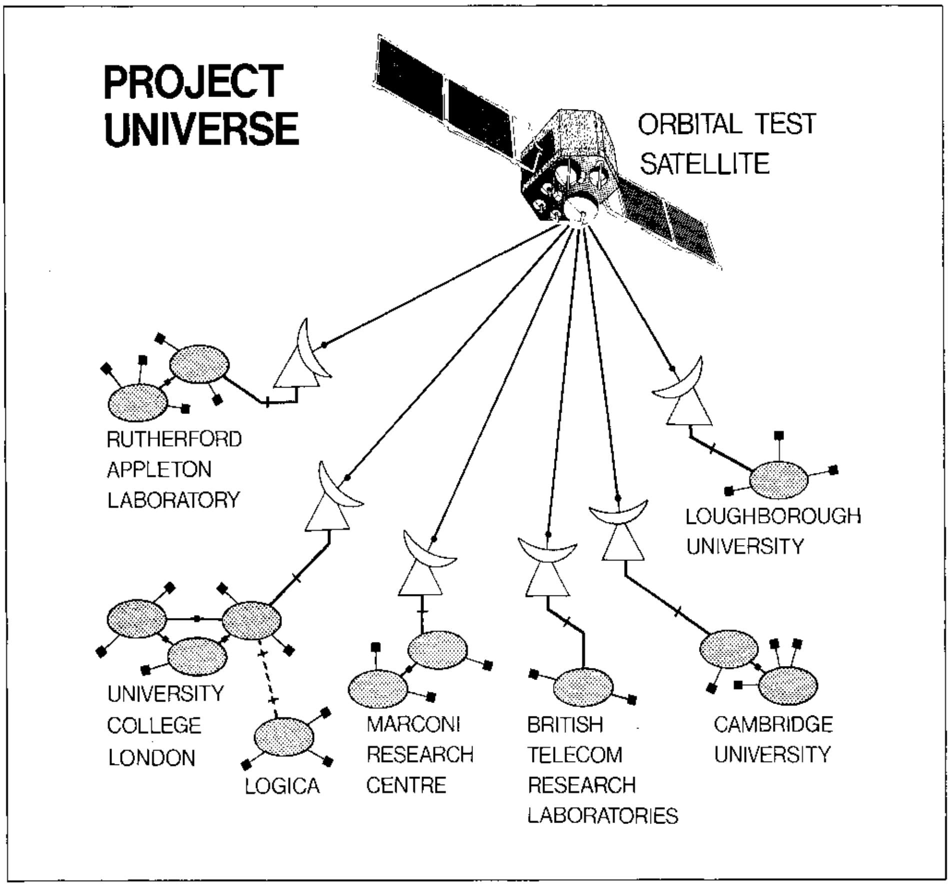
In addition, propane has also a very narrow Landau distribution and therefore, with 36 samples, the energy loss is obtained with a better accuracy than with the usual argon gas filling. The gas amplification is kept low to allow for good proportional properties. The system seems very near to a textbook example of a drift chamber working in the classical proportional region. Rutherford and Geiger would have approved.

STANFORD
Nuclear physics at SLAC

Now approved is a proposal by American University to build a new injector at SLAC for nuclear structure physics. The new 1.65 million dollar injector will feed electrons into the last 20% of the linear accelerator, providing beams of 0.5 to 6 GeV. The beam intensity will be a factor of ten higher than presently available from the full linac due to the reduced effects of beam breakup in the shorter length.

This high intensity and low duty cycle region is not covered by the medium energy electron facilities around the world or by the high energy beams at SLAC. This facility will be ideal for experiments in electron scattering from nuclear targets in the transition region between traditional low energy nuclear structure and the high energy region dominated by quark effects. The programme will use existing spectrometers and facilities at SLAC, concentrating on elastic and inelastic scattering from light nuclei. A polarized electron source can be added in the future to include

Project UNIVERSE, a UK study of the use of high bandwidth digital telecommunications.



spin transfer and parity violating measurements.

Construction began in October, and beam is expected by January 1985. There will also be funds for a programme of nuclear structure experiments to be called NPAS (Nuclear Physics at SLAC). A new Nuclear Program Advisory Committee is being formed and a call for proposals will be issued soon.

RUTHERFORD Project UNIVERSE

The Rutherford Appleton Laboratory (RAL) is participating in Project UNIVERSE, an imaginative research experiment in high bandwidth digital telecommunications. It spans a number of local area communications networks, making a single wide area network, serviced by high capacity satellite links.

UNIVERSE, short for UNIVersities Expanded Ring and Satellite Experiment, was originally proposed as an academic research project, but now involves also industrial and governmental installations.

The telecommunications links at six of the participating sites involve earth stations equipped with dish aerials and transmitting and receiving equipment communicating with the Orbital Test Satellite (OTS), orbiting 36 000 km above the equator and operated by the European Space Agency (ESA). The seventh site uses a land link. Transmission rates of 1 million digital bits (1 Megabit) per second are possible.

The project grew out of an earlier experiment at Cambridge (the so-called 'Cambridge Ring') and the STELLA project to investigate high bandwidth digital data transmissions between European physics research centres using the OTS satellite.

With RAL in the project are Loughborough and Cambridge Universities and University College, London, GEC-Marconi, Logica, British Telecom and the UK Department of Industry. RAL provides project management.

The experiment will enable valuable experience to be gained in the use of high bandwidth space communications to exchange the sort of information which is now the lifeblood of modern industry and commerce.

MICHIGAN Superconducting cyclotron completes first running period

On 1 July a celebration marked another milestone for the US National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University – the completion of a first nine month experimental running period of the world's first superconducting cyclotron (K 500), establishing this new kind of accelerator as an effective tool for nuclear physics, a goal towards which the Laboratory had been working for some ten years.

The beginning of the running period had been somewhat painful, requiring much debugging of the cyclotron, the beam transport and the experiments. Intensive effort by the operating group quickly led to improvements in reliability and in the later part of the period, successful stable running was regularly achieved. The celebrations marked the end of an experiment of a group from Stony Brook taking data on subthreshold pion production in collisions of nitrogen on silver.

The cyclotron is named for its energy parameter K which is 500 MeV (the quantity which when multiplied by the square of the charge number

Staff and students of the US National Superconducting Cyclotron Laboratory at Michigan, assembled around the K500 cyclotron and its r.f. superstructure.

of the accelerated ion and divided by the mass number gives the ion energy). The K500 is the first of a pair of superconducting cyclotrons being constructed at NSCL, the ultimate objective being operation as a coupled system so that projectiles from helium to uranium can be accelerated to energies up to 200 MeV/nucleon for the lighter ions and up to 25 MeV/nucleon for the heaviest.

The first running period began just two weeks before the First International Conference on Nucleus-Nucleus Collisions in East Lansing, at which the NSCL Laboratory was inaugurated. The conference gave a splendid launch to the experimental programme by presenting an overview of recent advances in an understanding of nucleus-nucleus collisions.

Beams accelerated by the K500 Cyclotron so far include deuterons, alphas, helium, lithium, carbon, nitrogen, oxygen, neon and argon ions. Some 800 hours of beam were delivered to fourteen experiments, about equally divided between experimenters from Michigan and outside user groups.

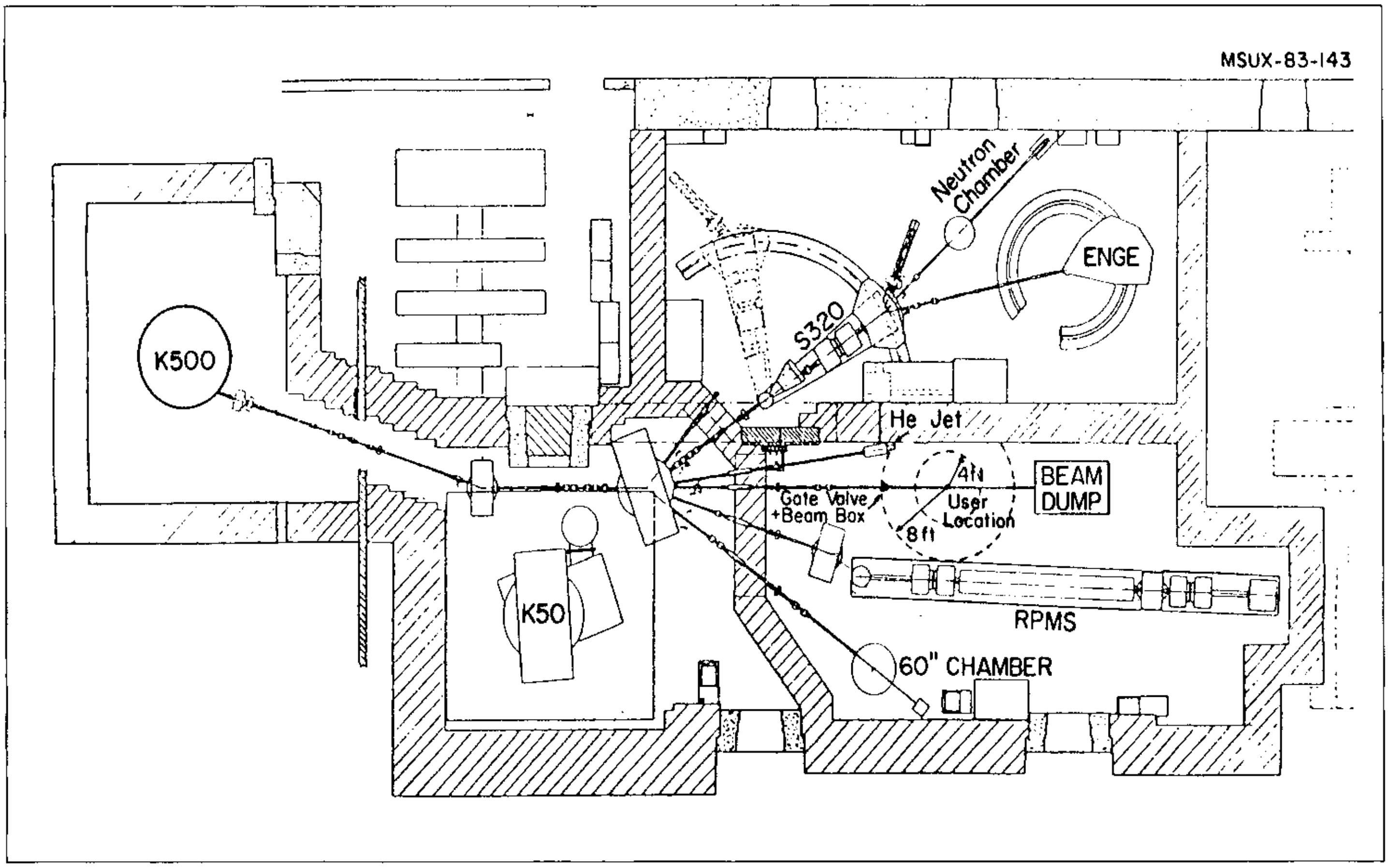
Beamlines feed two experimental rooms. In the south hall a 34° beamline feeds a 60 inch scattering chamber which provides versatile arrangements of large detectors both in and out of reaction plane. On an adjoining beamline the Reaction Product Mass Separator (RPMS) was used in test runs which confirmed its design mass resolution; a study of nuclei far from stability will begin in the second period using the RPMS. A third beamline feeds a small chamber for particle-gamma correlation studies and there is space for a fourth beamline for a cryogenic helium jet apparatus to give rapid transport of radioactive nuclides to remote detectors.

The north hall houses two magnetic spectrometers and a neutron facility. The first of these, the S320 spectrograph, is matched to the maximum after-target rigidity of beams from the cyclotron and is expected to be in high demand for studies of giant resonances and small angle fragmentation. It is also part of the beam transport system to the other spectrograph, an Enge splitpole, and to a neutron chamber. With the completion of the S320, the Enge spectrometer is then also operational; its short flight path is well suited to the detection of charged pions, and for studies of nuclei far from stability. Finally, the thin-walled neutron chamber with a well shielded beam dump provides a facility for experiments involving neutron detection.

A large proportion of the early experiments studied the evolution of reaction mechanisms from the characteristic low energy processes of fusion, fission, and deep inelastic scattering to processes of non-equilibrium emission, fragmentation, and other phenomena more characteristic of high energy collisions. In addition, several experiments started to explore the application of heavy ions in biology and medicine.

In one experiment, heavy fragments up to approximately mass 50 were produced in collisions of carbon ions at 30 MeV/nucleon with a silver target. The observed behaviour of the cross-section is reminiscent of critical phenomena in nuclear matter, analogous to the distribution of droplet sizes at the point of the phase transition between water and steam. This type of interpretation has been invoked to explain a similar production of fragments in reactions induced by 50 to 400 GeV protons at Fermilab. The results are also well described by a statistical evaporation model and more detailed studies will be required to make a distinction

Layout of the beamlines and experimental areas at the Michigan K500 cyclotron.



between the two interpretations.

Beams of 35 MeV/nucleon have hardly been available in the past and consequently considerable emphasis was placed on systematic studies of light particle production connecting previous investigations at both higher and lower energies. These light particles are believed to originate from localized zones of excitation, such as the nuclear fireball at high incident energies or localized hot-spots at lower energy. The initial experiments show that very detailed experiments with impact parameter selection will be necessary to determine whether hydrodynamic effects, unusual entropy production and other exotic phenomena are present at the intermediate energies of the K500 Cyclotron. Future experiments will require large arrays of detectors with sophisticated triggers to select impact parameters.

Several experiments focused on the question of momentum transfer from projectile to target nucleus, using radiochemical and electronic techniques. At low energies (below 10 MeV/nucleon) this transfer is known to be almost complete and the two nuclei fuse. At higher energies new reaction mechanisms of incomplete fusion, preequilibrium emission and few nucleon transfer become important.

Another experiment addressed a quite different topic, that of neutral pion production at an incident energy of 35 MeV/nucleon far below the required threshold energy in a nucleon-nucleon collision; the decay gamma rays from the neutral pion were detected in an array of lead-glass scintillators. Surprisingly large production cross-sections were found. The neutral pions appear to originate from a slowly moving source implying the cooperative action of many nucleons. Various intriguing models exist to account for the observation, such as a production mechanism akin to bremsstrahlung, a pionic instability of compressed nuclear matter, and a process where the nuclei fuse before creating the pions. In the next running period the availability of the Enge Spectrograph will allow an extension of these experiments to include charged pions.

Programmes have also been initiated on the application of heavy ions to problems in medicine, biology and agriculture. The beams can be used to deposit energy in individual cells for the study of the mechanisms involved in lethal and sub-lethal damage to mammalian cells. In the long term this line of research might address the important problem of repair of damage to DNA. The fragmentation of nitrogen has also been used in the production of radioactive nitrogen, which plays an important role in studies of denitrification and nitrogen fixation.

The K500 is now being upgraded with the aims of increasing the voltage-holding capabilities of the r. f. system and electrostatic deflectors for higher energies, increasing the reliability of the cryogenics, and reducing a first harmonic component in the magnetic field. The second period will also use lithium beams with energies of 20-35 MeV/nucleon. Work on Phase II, the K800 superconducting cyclotron and new experiments, is continuing. Construction of the magnet and r. f. system is well advanced.

Quark matter

For the third time in the past five years an international community of nuclear and particle physicists met to discuss the possibilities of colliding heavy nuclei at extremely high energies. The latest Conference, held from 26-30 September at Brookhaven, was the first to be held in the United States. During the past few years, these meetings have chronicled the rapid development of a new field of physics in which the fundamental properties of the strong interaction and the structure of the quark/gluon 'vacuum' can be studied through the macroscopic behaviour of nuclear matter under extreme conditions — conditions which probably do not exist in the present universe.

The possibility of creating such conditions in laboratory experiments through ultrarelativistic heavy ion collisions is attracting increasing numbers of physicists from both the nuclear and the particle communities. On the nuclear physics side in the US, a Department of Energy advisory panel has recently drafted a long-range planning study in which an ultra-relativistic heavy ion collider would be the highest priority new facility. In this respect the Brookhaven meeting came at a very critical moment: just weeks after the recommendations of the long-range planning study, and in the wake of the US High Energy Physics Advisory Panel's recommendation for a major change in US high energy physics planning.

At the earlier Quark Matter conferences, held at Bielefeld and Darmstadt, West Germany, discussions centred on the possibilities for grafting a heavy ion capability onto existing proton accelerators — specifically the ISR and SPS machines at

Brookhaven Director Nick Samios (left) and Maurice Jacob of CERN at the opening session of the recent International Conference on Ultra-Relativistic Nucleus-Nucleus collisions, held at Brookhaven.

At the Brookhaven Conference, there was a round table discussion on prospects for future experiments with ultra-relativistic nuclear beams. Left to right, J. D. Bjorken (Fermilab), D. A. Bromley (Yale), K. Nakai (Tokyo, back to camera) and A. Schwarzschild (Brookhaven). Partially obscured are M. Gyulassy (Brookhaven, behind Bromley) and R. Stock (GSI Darmstadt, behind Nakai).

(Photos Brookhaven)

CERN. At the Brookhaven meeting, for the first time the way seemed clear for realistic discussion of a dedicated machine optimized for the physics of nuclear beams.

Originally scheduled as a four-day meeting, the Conference was extended to allow a thorough examination of the issues raised by the planning study recommendation and the expected termination of the two colliding beam facilities which had seemed most promising for storing nuclear beams: ISR at CERN and CBA at Brookhaven.

The anticipated audience of about 100 participants swelled to nearly 300 by conference time. Representatives from four Laboratories — Brookhaven, CERN, Berkeley and Oak Ridge — described plans for major new experimental programmes with high energy nuclear beams, with each of the US Laboratories unveiling designs for dedicated heavy ion colliding beam facilities.

Following a day of reviews of the present status of theory and experiment, the Conference moved quickly to presentations of new results. Data just becoming available from cosmic ray balloon flights and measurements barely a month old from colliding alpha beams at the CERN ISR gave reinforcement to expectations that extremely high energy densities can be achieved in terrestrial experiments, and newly analysed data from Fermilab on the crucial question of nuclear stopping power provided the basis for improved estimates of the required collision energies. Calculations in lattice gauge theory are now at the point where fermions can be included, considerably improving the quantitative understanding of quark/gluon thermodynamics, and possible phase transitions from hadrons to a quark-gluon plasma.

Experimental techniques and measurement strategies were hotly debated in a remarkable session in which more than 100 experimentalists, roughly equally divided between nuclear and particle physicists, critically discussed the existing plans for experiments and the needs for developing new detector techniques. These working sessions culminated in a round-table discussion in which a distinguished panel of physicists representing Laboratories from the US, Japan and Europe stressed the diversity of approaches to this new physics, while emphasizing a strong consensus in the community regarding the need for heavy ion beams with collision energies on the order of 100 GeV/nucleon.

In closing remarks, both Gordon Baym and T.D. Lee emphasized the broad range of possibilities for new phenomena which could be revealed if the contemplated ultra-high energy densities are achieved in accelerator beams of heavy nuclei. T. D. Lee likened the spirit of the meeting to that of the 1st Rochester Physics Conference, a watershed of new ideas and challenging problems forming a common ground for previously divergent disciplines of science.

Proceedings of the meeting, which will be published by North Holland as a special volume of the journal 'Nuclear Physics', are expected to be available by March 1984.

(Report by T. Ludlam)

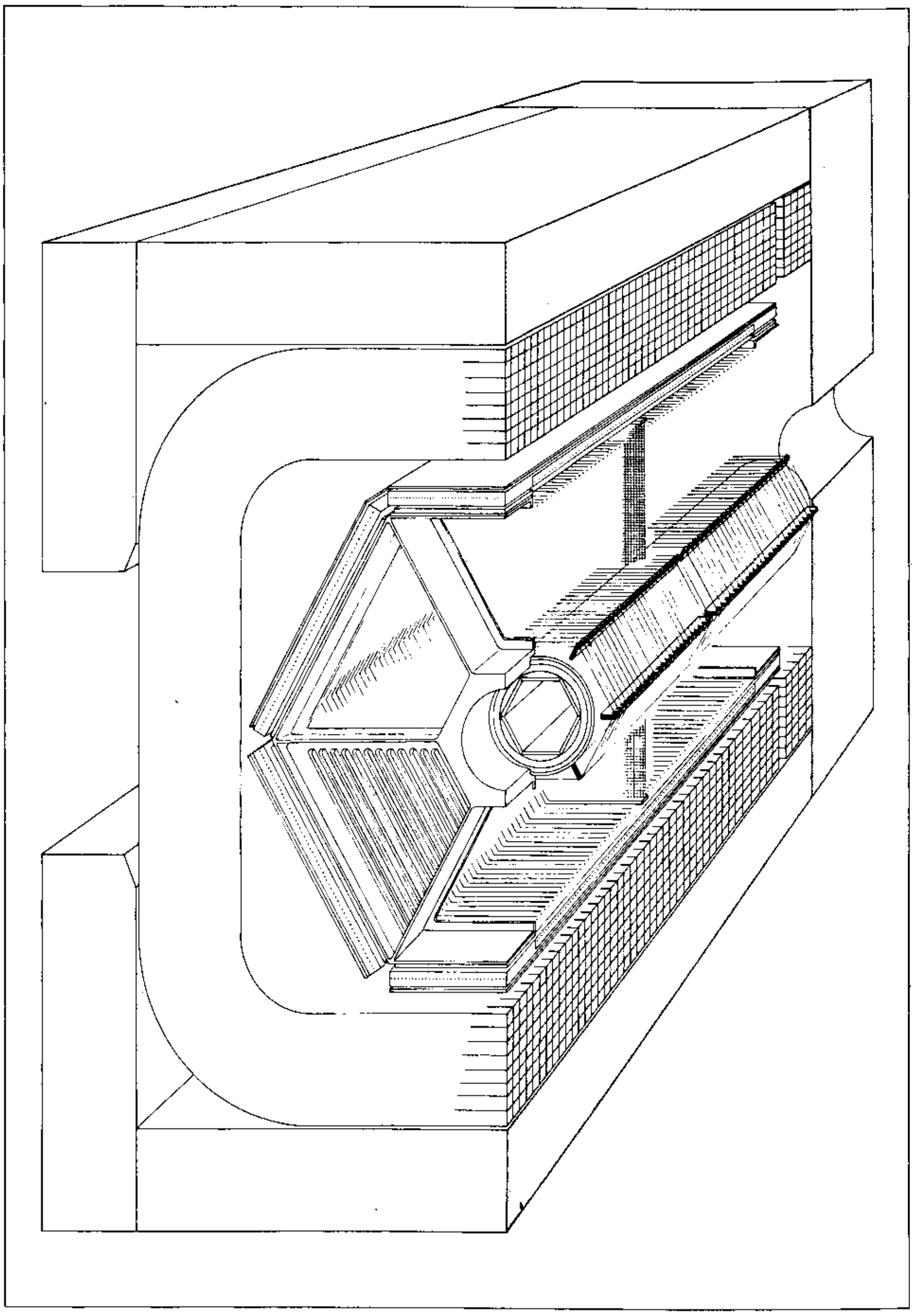
TPC Workshop

The first workshop to focus on time projection chambers was held at TRIUMF (Canada) this summer. Some 75 participants came from groups in Europe and North America using TPCs in a variety of applications in experimental physics. Reports included several general descriptions of existing detectors as well as some proposals for new instruments.

A time projection chamber (TPC) is the name given to a class of large volume drift chambers which operate generally with parallel electric and magnetic fields. Applications span energies from a few MeV in double beta decay searches, through intermediate energies in muon decay studies to large high energy arrays planned for LEP at CERN.

The TRIUMF TPC, described by D. Bryman, is being used to search for the lepton-number violating decay of a muon to an electron on a titanium target. It was perhaps the first to produce a physics result, having acquired data on about 2×10^{12} stopped muons, permitting a new limit on muon-electron conversion. The extensive measurements to understand the chamber and developments to improve its acceptance, resolution and rate capability were described. One highlight was a report on the status of the original TPC operating on PEP at SLAC. A. Barnes of Berkeley described experience with the chamber and emphasized efforts to understand and control factors affecting the resolution, especially gain stability required for the impressive energy loss resolution achieved. Meanwhile the superconducting coil of the PEP TPC has suffered some damage during tests, requiring repairs at Berkeley.

Isometric view of the TPC at TRIUMF currently collecting data in a search for (lepton-number violating) muon-electron conversion.



The ALEPH and DELPHI detectors, planned to operate in LEP experiments at CERN in the late eighties, will both incorporate TPCs as central detectors, and were described by L. Rolandi of Trieste and H. J. Hilke of CERN. Reduced-scale prototypes have been constructed to evaluate various new design concepts in endcap configuration, calibration and readout techniques. Both projects are major steps in the evolution of TPCs.

The Los Alamos TPC was described by W. Kinnison who showed how it will be used to obtain high precision measurements of muon decay parameters to test the standard electroweak theory. Development is continuing to improve the acceptance and resolution. Some innovative analytical techniques are used to obtain track reconstruction.

Two exotic variants were reported. A liquid argon TPC, considered to be a powerful tool with potential application to neutrino physics and proton decay, for example, was described by P. Doe of Irvine. A high pressure hydrogen gas TPC 'TREAD' (The Recoil Energy and Angle Detector) has been used in the tagged photon beam at Fermilab and was described by K. Goulianos of Rockefeller.

A combination of a TPC with an emulsion to obtain improved accuracy on wide angle tracks in a measurement of beauty lifetime was described by L. Rossi of CERN. There are tests on a low energy pion beam to study the problems of correlating tracks. Two proposals to use gaseous xenon TPCs to search for double beta decay in xenon were described by Rossi and A. Forster of Caltech. Encouraging Monte Carlo simulations and some preliminary studies of prototype chambers were outlined. A helium-filled TPC constructed at the University of California at Irvine, described by M. Moe, will shortly be used to look at double beta decay in selenium.

There were several discussions on detailed aspects of design and performance. F. Sauli of CERN described some of the basic processes in TPC-like gas detectors and how, for example, an optimization of suitable gas mixtures may be achieved. Some of the other topics raised were new geometries and techniques for endcap detectors, mechanical tolerance limitations on resolution and stability, calibration schemes with sources and lasers, problems with electrostatic uniformity in the drift region, and the incorporation of new developments in electronics into the next generation of readout schemes.

To give some perspective there were three reports on alternative techniques — the JADE jet chamber at DESY (R. D. Heuer), including an adaptation for relativistic heavy ions, DIOGENE at Saclay (J. Gosset) and SINDRUM at SIN (A. van der Schaaf).

The workshop was summarized by the father of TPCs — Dave Nygren of Berkeley — who must have felt some satisfaction at the widespread and varied applications of this technique which he and his group pioneered with the PEP proposal in the mid-seventies.

The occasion of the workshop was saddened by the sudden passing two days before of E.P. (Ted) Hincks of Carleton University who was one of the prime organizers and co-chairmen of the workshop committee. The success and usefulness of the workshop served as part of a fitting tribute to him.

Nobel Prizes

The common theme in this year's Nobel Prize for Physics, shared by Subrahmanyan Chandrasekhar of the University of Chicago and William A. Fowler of Caltech, is stellar evolution.

A star is formed from the gas and dust clouds which exist in the galaxies. Under the influence of gravity, a condensation slowly contracts to form a star. In this process, energy is released which leads to heating. Finally the temperature is high enough to set off nuclear reactions in the interior of the star. As a result, the hydrogen, forming the major part, is burnt to helium. This creates a pressure which stops the contraction and stabilizes the star so that it can exist for millions of years.

When the hydrogen has been consumed, other nuclear reactions take over, particularly in the more massive stars, and increasingly heavy elements, up to iron, are formed. When the evolution has reached this stage, the star can no longer resist gravity, and it undergoes some form of collapse, the exact nature of which depends on its mass. In some instances the collapse takes the form of an explosion whose visible result is the creation of a supernova. This brings about a brief but extremely intense flow of neutrons, which leads to the formation of the very heaviest elements.

For less heavy stars having a mass of the order of our Sun, the collapse gives rise to a so-called 'white dwarf'. The matter has here been compressed so that one cubic centimetre weighs around a kilogram. The electron shells of the atoms have been crushed and the star consists of atomic nuclei and electron gas.

For slightly heavier stars, the final stage is an even more compressed state in which electrons and nuclei unite to form neutrons. For the heaviest stars having a mass in excess of a few Solar masses, the force of gravity becomes so strong that the matter simply disappears in the form of a so-called 'black hole'.

Stellar evolution provides examples of physical processes which cannot be observed under laboratory conditions. Many scientists have studied these fundamental questions, but Chandrasekhar and Fowler

People and things

are the most prominent, according to the Royal Swedish Academy of Sciences, which awards the Nobel prizes.

Chandrasekhar's work deals with a large number of features in stellar evolution. A major contribution is the study of the stability problem in different phases of the evolution. In recent years he has studied relativistic effects, which become of importance because of the extreme conditions arising during the later stages of stellar evolution. Chandrasekhar's possibly best-known achievement, accomplished when he was in his 20s, is the study of the structure of white dwarfs. These earlier investigations have gained renewed interest in recent years with the advent of space research and modern astronomical techniques.

Fowler's work deals with the nuclear reactions which take place in the stars during their evolution. In addition to generating the energy which is radiated, they are of importance because they lead to the formation of the chemical elements from the original matter, which chiefly consists of the lightest element, hydrogen. Fowler has done extensive work on the experimental study of nuclear reactions of astrophysical interest, as well as carrying out theoretical calculations. Together with a number of co-workers, he developed, during the 1950s, a theory of the formation of the chemical elements in the universe.

On people

Among the physicists receiving the prestigious US National Medals of Science from President Reagan this year were Yoichiro Nambu of the Enrico Fermi Institute, Chicago, and Edward Teller.

Theorist Abraham Pais of Rockefeller won the 1983 American Institute of Physics — US Steel Foundation Science Writing Award for his book 'Subtle is the Lord: The Science and Life of Albert Einstein'.

First recipients of the new Tomalla Prize for work in Gravitation and Cosmology are Subrahmanyan Chandrasekhar of Chicago, and Soviet theorist Andrei Sakharov. The prize, established by a German industrialist, will henceforth be

On 23 October, Viktor Weisskopf celebrated his 75th birthday at a small gathering in the CERN Theory Division, where he has been spending some time this year. Many friends were there to express their heartfelt wishes for many more happy returns.

Accelerator physicist Godfrey Saxon retired from Daresbury Laboratory earlier this year.

awarded every two or three years. The first awards will be made in Zurich in January. Professor Chandrasekhar also shares the 1983 Nobel Physics Prize (see page 431).

Godfrey Saxon retires

Accelerator physicist Godfrey Saxon has retired from the Daresbury Laboratory. He began his career with Metropolitan-Vickers where he worked on radio and radar techniques. In the late 40s these techniques were applied to pioneering work on small linear accelerators used for cancer treatment. This resulted in the installation of many such linacs around the world and led to larger machines for scientific use, culminating in the first DESY injector in the early 60s. He also worked on Alvarez proton linacs for the first CERN injector and for the PLA at the Rutherford Laboratory.

He joined Daresbury in 1964 and expanded his interests to include electron synchrotrons and storage rings, making major contributions to the 5 GeV NINA synchrotron and the 2 GeV SRS storage ring. He will not be inactive in retirement, becoming a consultant for LEP, for the European Synchrotron Radiation Project, Rolls Royce Ltd., the Daresbury SRS and the SOR-Ring facility at Okazaki in Japan.

Kurt Symanzik

Kurt Symanzik of the University of Hamburg and DESY died on 25 October at the age of 59. During his life, this eminent theorist made many important contributions to quantum field theories. A tribute will appear in our next edition.

Pocket accelerator

A portable 8 MeV electron linac has been developed at Los Alamos National Laboratory with a view to applications in radiography, particularly in the area of non-destructive examinations in the construction industry. The electron beam produces X-rays from a metal target and can also provide a beam of neutrons. The X-rays or neutrons are used for radiography. The accelerator can be dismantled and transported in sections by two men. It will run off normal mains supply and is robust enough to operate under extreme climatic conditions.

At Stanford, two new beamlines are to be added to the SPEAR ring to provide additional facilities for basic research using synchrotron radiation. As well as electron-positron collisions for particle physics, the SPEAR ring is also operated with electron beams, providing synchrotron radiation. This research is co-ordinated by the Stanford Synchrotron Radiation Laboratory.

1984 CERN School of Physics

Organized in collaboration with the University of Bergen, the 1984 CERN School of Physics will be held from 11-24 June at Loftus/Hardanger, Norway. The School is intended for young experimental physicists with at least one year of research experience, and aims to teach various aspects of high energy physics, especially theory. Completed application forms, accompanied by a letter of support from the applicant's supervisor and a summary of present work (about 100 words, in English) should reach the CERN Scientific Conference Secretariat before 23 March 1984. Further information and application forms available from: D.A. Caton, Scientific Conference Secretariat, CERN, 1211 Geneva 23, Switzerland.

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Please reply in writing as soon as possible, outlining qualifications and experience to:

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EXPERIMENTAL PARTICLE PHYSICS

The High Energy Group at the University of California, Santa Barbara is seeking candidates for two postdoctoral research positions, with some flexibility in level, depending upon the qualifications of the individual. Capable, talented physicists are sought for participation in a very active program which provides a variety of opportunities for someone with ideas and initiative. Of the four main areas in the current program, one involves the tagged photon spectrometer at Fermilab. For a Tevatron run in Fall 1984, a silicon microstrip detector system is being added. The second experiment is PEP-9, which is starting to produce results on two-photon annihilation, but which will continue running for some time at SLAC. The third experiment, double beta decay, involves apparatus, presently being assembled, which is an order of magnitude larger than previously used in this field. The fourth area concerns planning and working on the future experimental program.

Interested candidates should write to the
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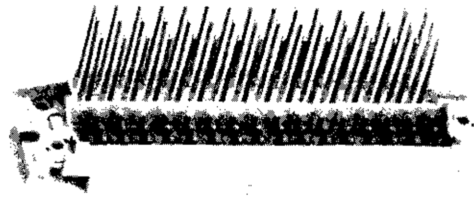

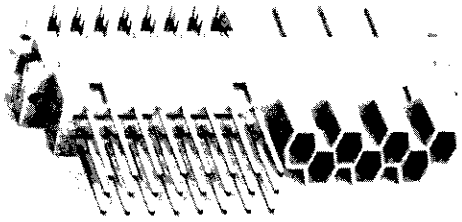

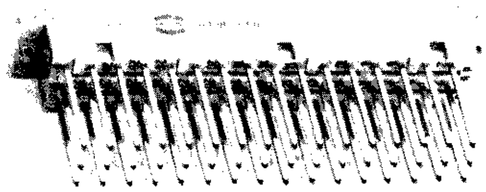

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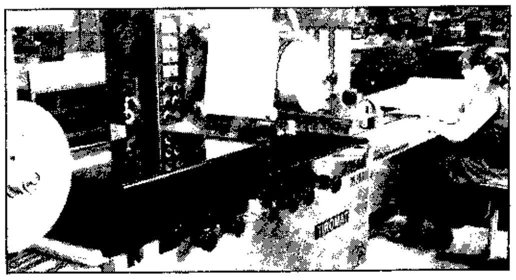

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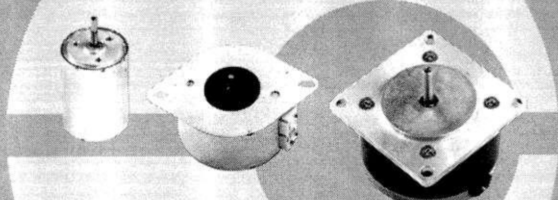

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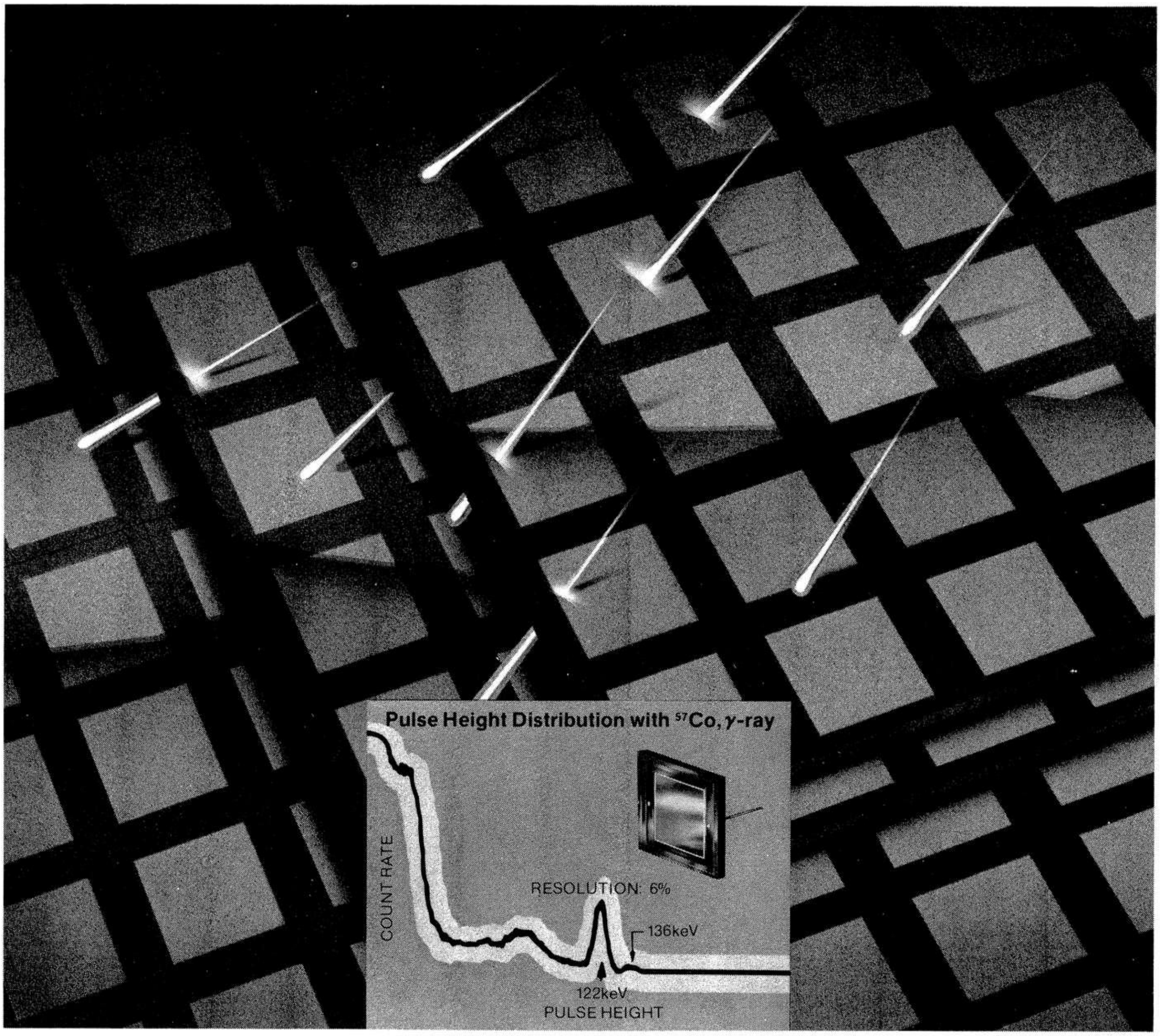

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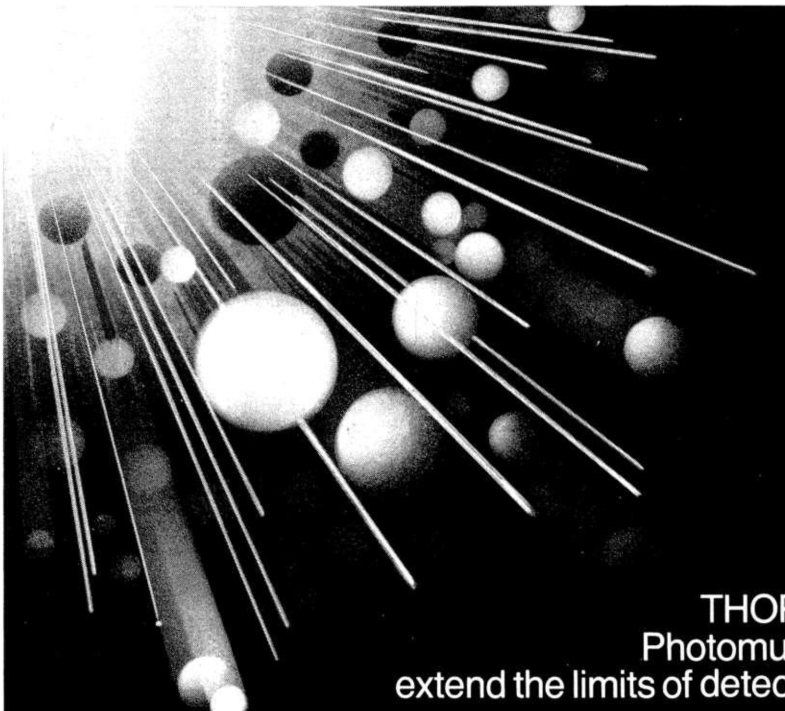

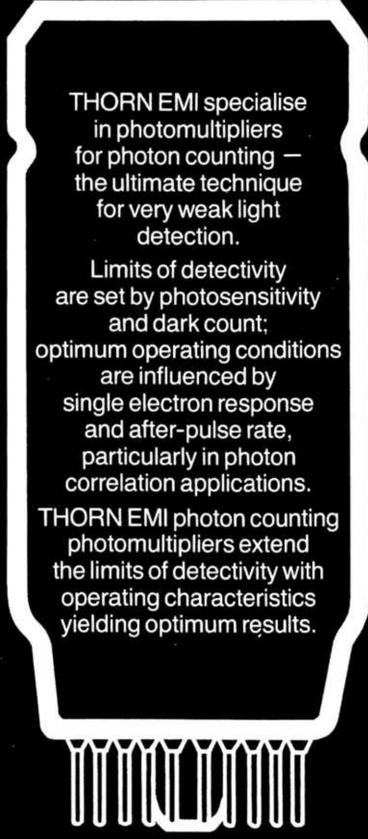

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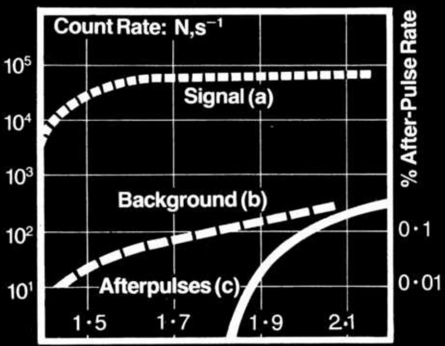

Fig 1

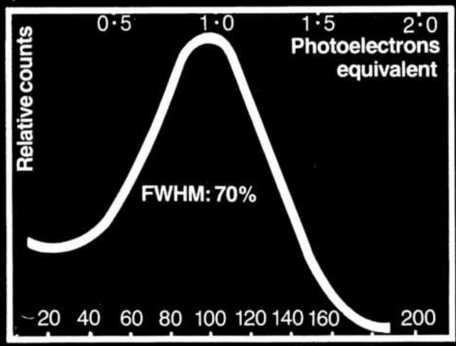

Fig 2

Fig 1 — Typical integral count rate characteristic: a) single photon source; b) background distribution; c) after-pulse rate in % per photoelectron.

Fig 2 — Single Electron Response

Fig 3 — THORN EMI Photon Counting Photomultipliers.

Tube Type	Cathode Type	Photo-Sensitivity (µA/lm)	Dark Count (counts per second at 20°C)	Single Electron Response (peak to valley)	After-Pulse Rate (No. of pulses in a fixed time window above a fixed threshold, as %/input photoelectron)		
					Threshold (p.e)	Time Window (µs)	Rate (%/p.e.)
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9798	SbNaKCs	160	1000	1·5	2	0·3 to 2·3	0·1
9902	SbRbCs	85	200	2	2	0·3 to 2·3	0·04
9883	SbKCs	75	200	2·5	2	0·3 to 2·3	0·1
9863/100	SbNaKCs	180	50	1·2	0·5	0·075 to 0·125	0·1
9863/350	SbNaKCs	180	300	1·2	0·5	0·075 to 0·125	0·1

Fig 3

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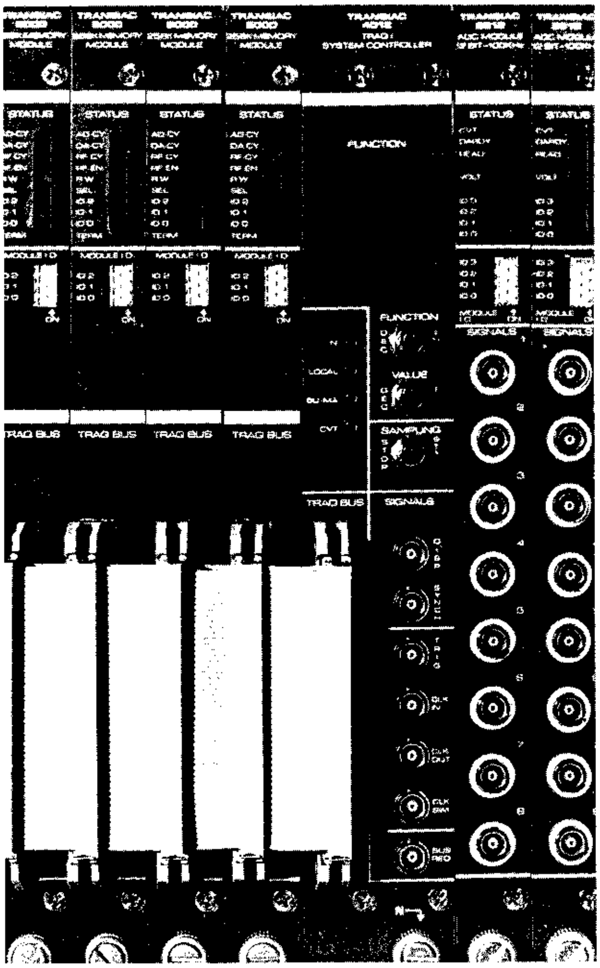

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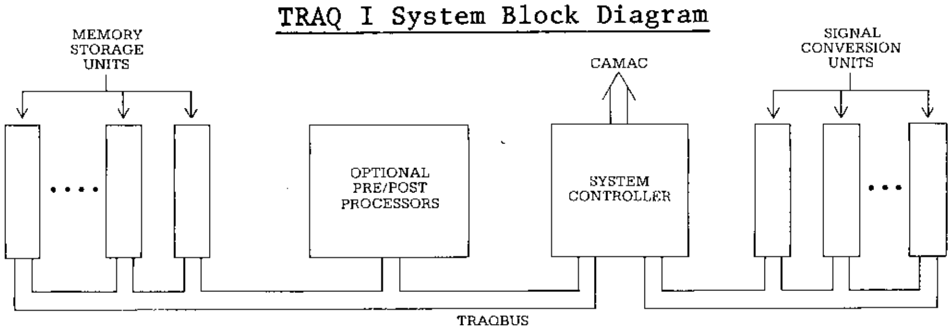

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