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Cover photograph: An observant photographer caught this picture of fingers in action during the International Symposium on Polarized Beams and Targets held at Argonne. The fingers are pointing to indicate the directions of the spin axis for the beam proton and the target proton. The three participants appear to have different opinions as to the optimum configuration. (Photo Argonne)

Experimental programme at the SPS

The Editor whishes to acknowledge the help of Jim Allaby, for many years coordinator of the SPS experimental programme, in putting together this review.

Within the next few weeks it is expected that the first high energy particles generated by the CERN 400 GeV proton synchrotron, the SPS, will be fed to experiments in the West Area. It seems an appropriate time to cover the programme of research which is planned for the first years of operation of Europe's new machine.

The SPS has two beam extraction systems — one sending protons towards the West Area and the other towards the North Area. The North Area is scheduled for completion in a little over a year's time so this review will concentrate on the experiments lined up for the West Area, many of which are ready and raring to go.

The protons going West can be used in the following ways:

1. The beam can be transported to the surface from the underground accelerator and split at the entrance to the West Hall between three targets to provide beams of secondary particles. The West Hall existed prior to the building of the SPS and it is not long enough to accommodate experiments capable of handling the highest energy particles generated by the accelerator. The space available for shielding is inadequate to be effective for protons of energy above 200 GeV. Thus the proton beam to the Hall will be limited to a peak energy of 200 GeV and the secondary beam-lines are designed to transport particles with energies up to 150 GeV. All the beam-lines can operate simultaneously with 200 GeV protons on the targets. The present schedule plans for protons on the targets on 22 October so that tuning of the secondary beams in the West Hall should be under way early November.
2. The extracted beam can be directed onto a target below ground close to the machine and secondary particles from this target can then be transported, in the same tunnel as is used for the beam-line taking protons to the West Hall, to the surface and along the Hall to the 3.7 m European bubble chamber, BEBC. The extra transport distance available because of producing the particles underground makes it possible to install r.f. separators with a 500 m drift distance between them to produce a fully separated beam of kaons at energies up to about 75 GeV or antiprotons at energies up to about 110 GeV for BEBC.
3. Alternatively, the extracted beam can be directed onto another underground target for the production of a neutrino beam. To achieve maximum neutrino energies and intensities this target will receive protons at the peak energy of 400 GeV. Pions and kaons emerging from the target will be focused and directed at the neutrino detectors by one of two systems. They can traverse a distance up to about 430 m during which they decay to produce neutrinos. The neutrinos will pass through shielding, 180 m of steel and 170 m of earth which absorbs the muons produced in the pion and kaon decays, before emerging about 50 m upstream of BEBC. They will pass successively through BEBC, two counter experiments and the heavy liquid bubble chamber, Gargamelle. One of the focusing systems is a magnetic horn and reflector which focuses pions and kaons over a wide range of momenta to give a 'wide band' neutrino beam. With the other system the pions and kaons of a particular momentum are selected by bending magnets and then focused by quadrupoles. Their subsequent decay gives neutrinos clustered in two momentum bands — one corresponding to the kaon parents and the other to the pion parents. This is a 'dichromatic' or 'narrow band' neutrino beam; it is of lower intensity than the wide band but the neutrino energies are much better known.

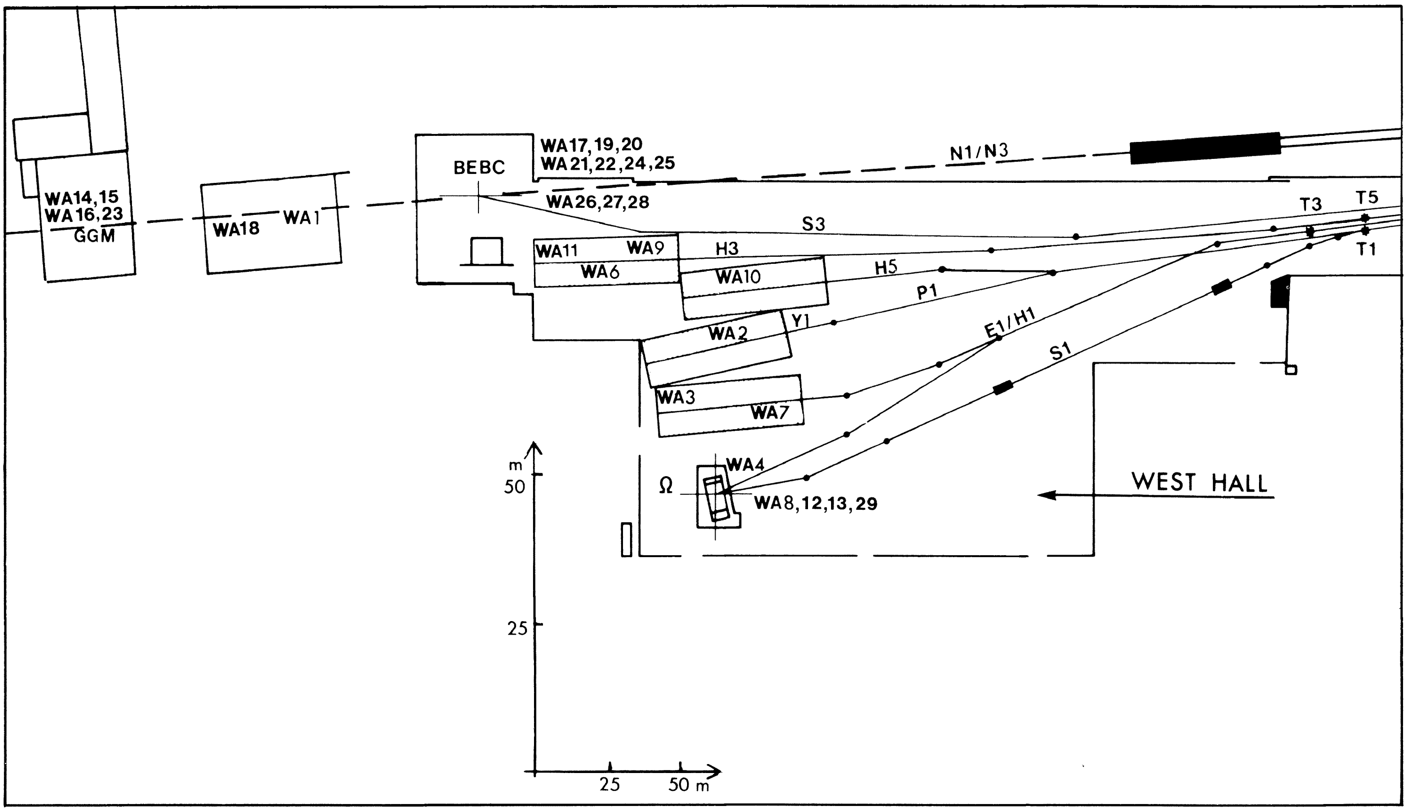
The neutrino experiments

Much of the present excitement in high energy physics is centred around data from neutrino experiments and they therefore have high priority in the SPS programme. For these experiments BEBC can be used in a variety of ways. The chamber filling can be hydrogen, deuterium or a hydrogen-neon mixture. It will also be possible to use a track sensitive target, TST (see February issue, page 47), filled with hydrogen to retain the simplicity of the proton target nucleus, and surrounded by a hydrogen-neon mixture to improve the detection of neutral particles. An external muon identifier, EMI (an array of wire chambers described in the April issue, page 137), spanning a wide angle outside the BEBC iron shield will add further information to that from the bubble chamber pictures themselves. BEBC is scheduled to start running mid-November with a hydrogen-neon mixture and the TST will be installed next Spring.

The approved neutrino experiments in BEBC are as follows, in numerical order according to the number they were assigned at the time of approval:

WA 17 An Ankara/Brussels/CERN/Dublin/University College London/Rome/Strasbourg/Turin collaboration are returning to the nuclear emulsion technique in combination with BEBC to attempt to spot charmed particles and to learn more about the interactions where two leptons are produced. These dilepton events may be linked to charmed particles. They will fire the wide band neutrino beam through a 100 kg stack of nuclear emulsion positioned in front of BEBC which will be filled with hydrogen. The EMI will be in action. Appropriate events recorded in BEBC which can be traced back to an interaction in the emulsion will be measured so as

General layout of the beams and experiments in the West Area of the CERN 400 GeV proton synchrotron, the SPS. The beams enter from the right. Neutrinos (wide band and narrow band beams) take the beam-line N1/N3 into the BEBC 3.7 m European bubble chamber, the counter experiments (WA 1 and WA 18), and the heavy liquid bubble chamber, Gargamelle. Separated particles take the beam-line S3 to BEBC. Protons of 200 GeV reach targets T1, T3 and T5 to provide a variety of secondary beams into the West Hall. The different experiments, WA 1 to WA 29 are described briefly in the text.



to locate the position in the emulsion where the interaction occurred. This will avoid the impossibly tedious task of searching all the emulsion stack for interaction tracks of interest and the special ability of nuclear emulsions will then be called into play. Particles with lifetimes in the range 10^{-11} to 10^{-14} s will leave a visible track in the emulsion and the tracks can be measured with great accuracy. In favourable cases, it should be possible to calculate the mass of the short-lived particle. It will also be possible to look in detail at the vertex of the dilepton events.

WA 19 An Aachen / Bonn / CERN / Oxford collaboration will use dichromatic neutrino and antineutrino beams into a hydrogen-neon mixture. Differential cross sections will be studied in charged current interactions (where the neutrino converts to a muon) and there will be detailed analysis of neutral current interactions where no muon is produced. They will also look for dilepton events and compare those producing two muons with those producing a muon and an electron.

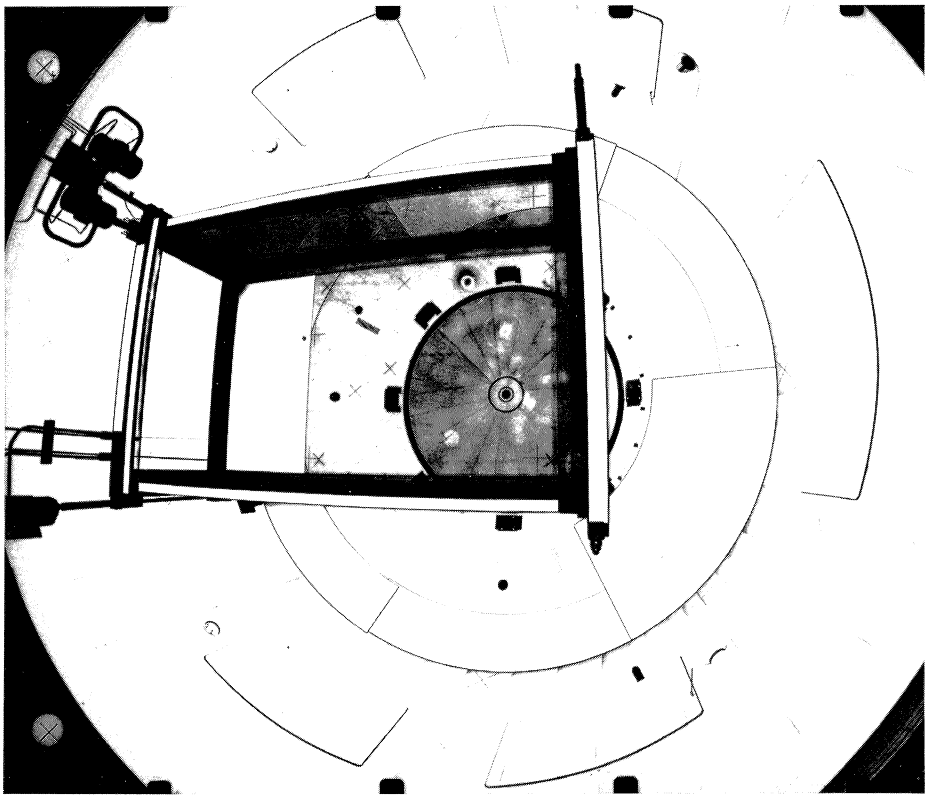
WA 20 The Aachen / Bonn / CERN / Oxford collaboration will also carry out a search for 'funny' neutrinos. The 400 GeV proton beam will be ploughed directly into the large iron beam dump which normally absorbs the unwanted pions and kaons when the dichromatic beam is being operated. Because of the large size of the dump, the pions and kaons, which normally escape from the target and decay to give the familiar muon-type neutrino, will be almost all absorbed by strong interactions in the nuclei in the dump before they decay. An unknown type of neutrino might, however, still be produced if its parent particle is very short-lived and decays before being absorbed. The heavy lepton for which there is evidence at the SPEAR storage ring at Stanford would probably have its own type of neutrino and might be spotted in this experiment because of something peculiar about the event rate at which neutrino interactions occur in the chamber or about the sort of interactions that are seen.

WA 21 The Aachen / Bonn / CERN / Oxford collaboration will use the wide band neutrino beam into hydrogen to look for charmed particles via their 'signature' of events where the change in strangeness is not equal to the change in charge (violation of the $\Delta S = \Delta Q$ rule). This signature is evident in a charmed particle candidate picture from Brookhaven. At the same time, they will test predictions of the quark model by measuring the cross sections for the production of N^* and Δ resonances and will check for violations of charge symmetry.

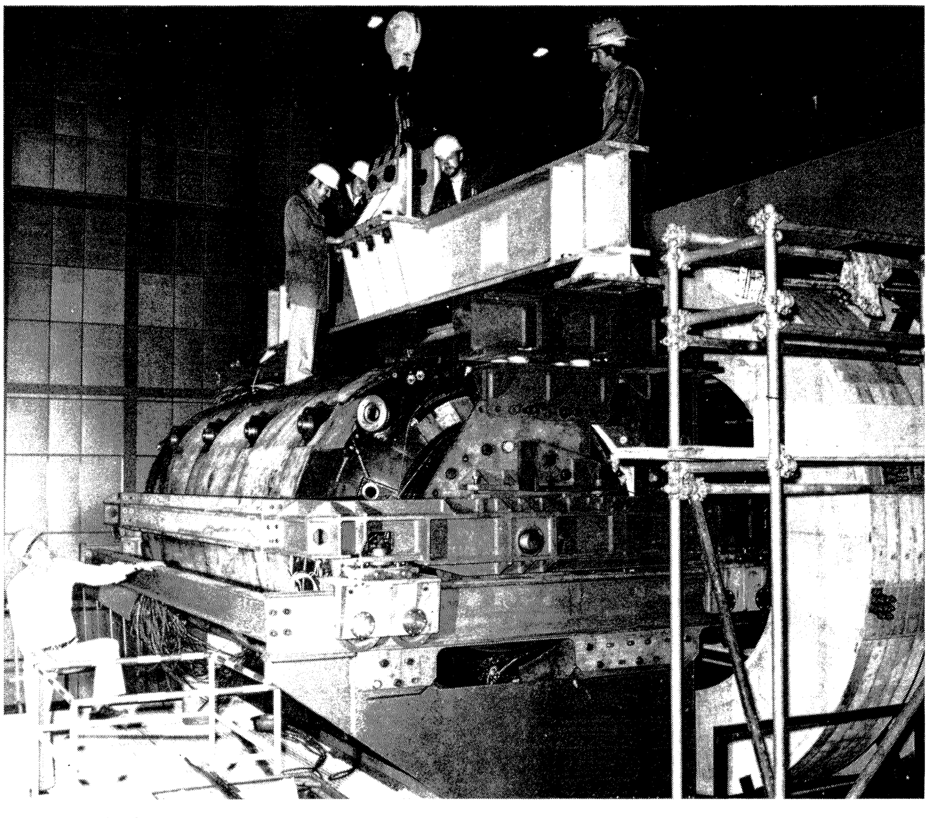
WA 22 An Imperial College London/CEN Saclay collaboration will search for differences in the behaviour of neutrinos from pion decay and those from kaon decay. They will, obviously, use the dichromatic beam and have the chamber filled with a hydrogen-neon mixture. In particular, it will be intriguing to look at the rate at which the two types produce strange particles in the interactions. The kaon is a strange particle built with a strange quark; the pion has no strange quark. Will the kaon neutrino somehow carry with it some memory from whence it came and be more frequently involved in strange particle producing interactions?

WA 24 A Bari/Brussels/Ecole Polytechnique / Rutherford / Saclay / University College London collaboration will use wide band neutrino and antineutrino beams into the TST. The combination of the simplicity of the proton target with the high neutral particle detection efficiency of the surrounding mixture should make it possible to study some rare interactions particularly those producing strange particles. These would include interactions where the $\Delta S = \Delta Q$ rule is obeyed (such as antineutrino and proton giving a positive muon, lambda and pions with total charge zero) and charmed particle candidates where the $\Delta S = \Delta Q$ rule is not obeyed (such as neutrino and proton giving muon, lambda and pions with total charge +2). They will also study charged current events and electron-type neutrino interactions.

WA 25 An Amsterdam/Bologna/Padova / Pisa / Saclay / Torino collaboration will use wide band neutrino and antineutrino beams into deuterium to study interactions on both protons and neutrons (distinguishing between the two by the total charge of the emerging particles). The structure



The 3.7 m European bubble chamber, BEBC, will be fitted with a track sensitive target, TST. The TST is filled with hydrogen, to retain the simplicity of the proton nuclei as target particles in the interactions, while the surrounding volume is filled with a hydrogen-neon mixture to improve the detection efficiency for neutral particles. The photograph shows a prototype TST mounted in BEBC during the Spring of this year.



The heavy liquid bubble chamber, Gargamelle, was moved during the Summer from its position at the 28 GeV proton synchrotron, where it was the scene of some excellent physics including the discovery of neutral currents, to the West Area at the SPS. The picture shows the installation of the chamber body. Reassembly should be complete by the end of February 1977 and neutrino physics with the chamber will probably begin in the Spring.

CERN 170.8.76

The huge detection system of the WA 1 neutrino experiment. It consists of magnetized iron toroids interspersed with drift chambers and scintillation counters. Assembly of the system is nearing completion and tests with the neutrino beam will probably begin in December.

functions will be determined from the cross sections of the interactions on protons and on neutrons.

The Gargamelle bubble chamber will be used for neutrino experiments filled with a mixture of freon and propane. It will have its own EMI. The experiments are:

WA 14 A Bari/CERN/Ecole Polytechnique/Milano/Orsay collaboration will use the wide band neutrino beam to study leptonic neutral current interactions where the neutrino scatters elastically on an electron. They will also keep an eye open for elastic-like scatter on an electron which could give inverse beta decay producing a muon and an electron type neutrino. Other subjects of interest in the same pictures are dilepton events, electron-type neutrino interactions, the production of vector mesons by neutral current interactions and the production of strange particles. The EMI will help in many of the measurements.

WA 15 An Aachen/Bergen/Brussels/Strasbourg/and University College London collaboration will use the wide band antineutrino beam to study leptonic neutral current interactions (with the antineutrino scattering on an electron), dilepton events, positron-type neutrino interactions and charm particle candidates where a muon, electron and a V^0 particle are produced. This experiment is largely the antineutrino version of WA 14 and there will be important comparisons to be made between the two sets of data.

WA 16 A CERN / Ecole Polytechnique/Orsay/Strasbourg collaboration will use the dichromatic neutrino beam up to the highest energy of the neutrino parents (275 GeV). They will look at dilepton events and try to establish the threshold energy at which the two muon events start to happen and will examine whether muon, electron events occur at the same rate as the two muon events. They will also look at average particle multiplicities at different neutrino energies (up to 240 GeV), at neutral strange particle production and at features of the shower of hadrons which emerge in neutral current events. The EMI will be in action plus a small calorimeter added downstream of Gargamelle to give additional information on hadron energies.

WA 23 A CERN/Milan/Orsay collaboration will use the dichromatic neutrino beam (and, later, the antineutrino beam) at low energy where the neutrinos from the pion and kaon are well separated in energy and those from kaons give only 10% of the interactions. The energy of the incoming neutrinos will be well known and the energy dependence of various types of interaction will be rather clearly determined. They will study such things as the neutral current total cross sections, the production of strange particles in neutral current interactions, the charged current to neutral current ratio, . . .

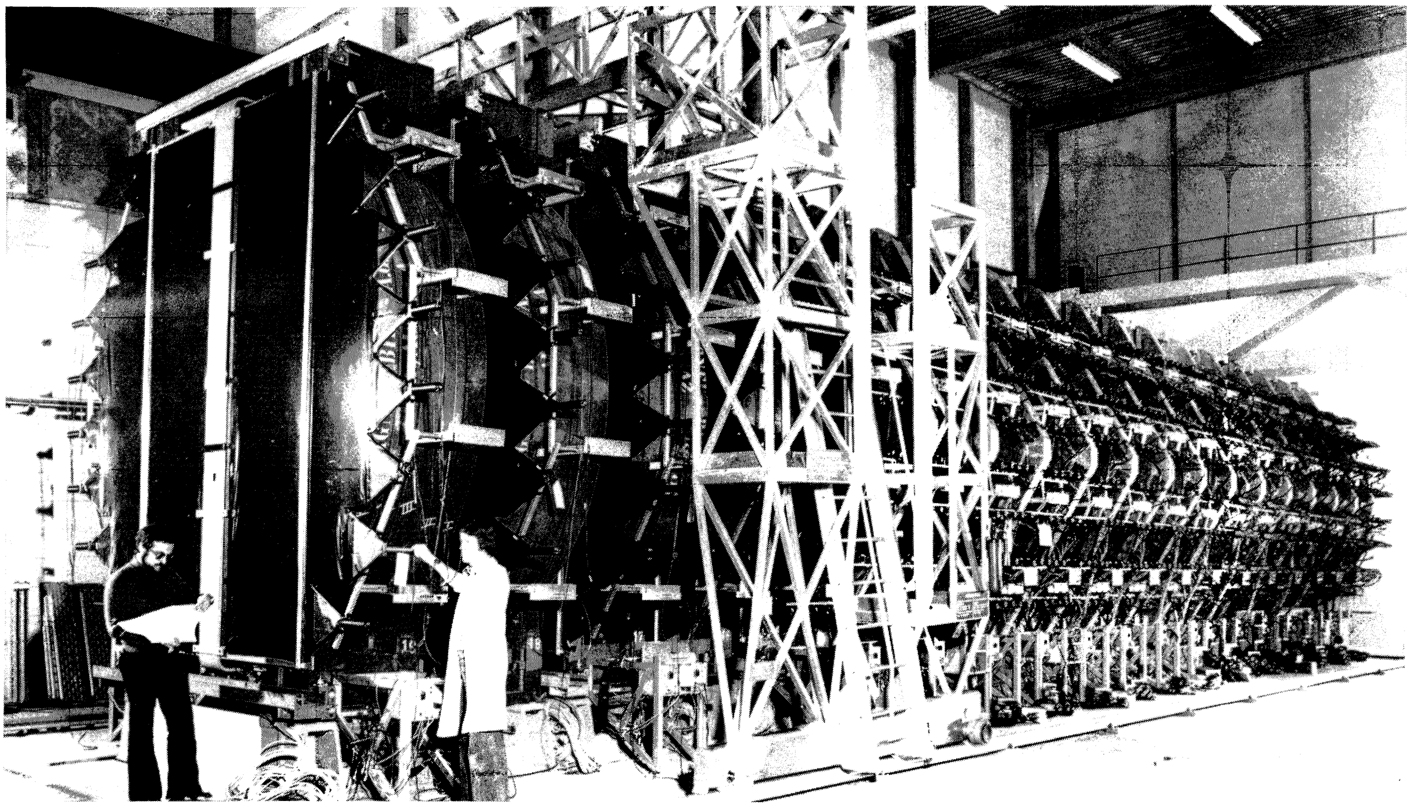
Sandwiched between the BEBC and Gargamelle bubble chambers are the detection systems for the two counter experiments which will study neutrino interactions —

WA 1 A CERN/Dortmund/Heidelberg/Saclay collaboration have assembled a detector 20 m long with a total mass of about 1400 tons consisting of iron cored toroidal magnet modules (0.9 m long, 3.75 m in diameter) interspersed with drift chambers and scintillation counters. With this target-calorimeter system it will be possible to measure energies by pulse height analysis from the scintillators and to measure the muon momentum by magnetic deflection. They will study inclusive neutrino interactions in the iron and search for rare processes such as the production of three leptons, inverse muon beta decay (like WA 14), heavy leptons and intermediate bosons (Hope springs eternal in the human breast!). By installing, in front of the detector, a $35\ m^3$ dewar, which can be filled with hydrogen or deuterium, plus an array of multiwire proportional chambers to identify the interaction vertex, it will be possible to compare neutrino interactions in hydrogen and deuterium.

WA 18 A CERN/Hamburg/Moscow (ITEP)/Rome (INFN) collaboration will perform the other counter neutrino experiment which will be added onto the back of WA 1 and may be ready for action in about a year's time. It involves a fine grained target calorimeter, to measure energies and directions of hadron jets coming from neutrino interactions, and a muon detector. The fine grained calorimeter consists of 13 modules, each with six $3 \times 3\ m^2$ target plates of marble 8 cm thick, with gaps for 20 scintillation counters and proportional counters. This is followed by a magnetized iron calorimeter. The proportional counters identify the interaction vertex and the scintillators measure energies by pulse height analysis. Some of the muons produced in the WA 1 detector can stop in the WA 18 detector and their polarization can be determined by observing their decay asymmetry. The aims are to study inclusive semi-leptonic neutral current neutrino interactions, to measure muon polarizations in antineutrino interactions and in dimuon events and also to search for new particles.

Counter experiments in the West Hall

The spectrum of physics to be covered by the counter experiments in the West Hall is broad and it includes several investigations into the world of charmed particles.



CERN 1.10.76

WA 2 A Bristol/Heidelberg/Geneva/Orsay/Rutherford/Strasbourg collaboration will study the leptonic decays of hyperons. In a spectrometer which includes drift chambers, a Cherenkov counter, a gamma hodoscope and a lead-glass array, they will make very accurate measurements on the decays of ksis and sigmas. Assembly of the hyperon beam-line, which has superconducting magnets to shorten the path lengths of the short-lived hyperons, and of the detection system is almost complete. It is expected that it will be possible to produce a 100 GeV beam containing some ten thousand negative sigmas. With this sort of intensity and the accuracy of the detection system it should be possible to pin down some parameters of the hyperons, the strange relatives of the proton, better than ever before.

WA 3 An Amsterdam/CERN/Cracow/Munich/Oxford/Rutherford collaboration will study two body hadron reactions using pion and kaon beams with energies up to 100 GeV. The detection system involves a beam telescope of multiwire proportional chambers (MWPCs), a two-magnet spectrometer with wire spark chambers (which will gradually be replaced by drift chambers) and two large Cherenkovs. They will investigate the momentum transfer and energy dependence of the different possible interactions and try to learn more about $\pi\pi$ and $K\pi$ interactions. They will also look for high mass resonances. The detection system is built and the experiment will be amongst the first to take data.

WA 4 A Bonn / CERN / Daresbury Laboratory/Ecole Polytechnique/Glasgow / Lancaster / Manchester / Orsay/Sheffield collaboration will study the photoproduction of hadrons using tagged photons of energy up to 70 GeV fired into the Omega spectrometer. The detection system is completed by Cherenkov counters, scintillator hodoscopes and a lead glass photon detector. First priority will be given to a search for charmed particles. The use of a photon beam onto a hydrogen target is a very clean way to do such a search. The experiment is ready to start work on the tagging system when the SPS provides its first particles while the rest of the Omega detection system is completed and its results are eagerly awaited. Subsequently a long programme of investigations on vector meson photoproduction, Compton scattering, etc... will be carried out.

WA 6 A CERN / Padova / Trieste / Vienna collaboration will analyse the role of particle spin in high energy hadron interactions. They have a polarized target (propanediol) in a 1 m diameter magnet with a large exit solid angle to allow low energy particles to escape for detection. A forward spectrometer has MWPCs, scintillation counter hodoscopes and a Cherenkov. They will study interactions with incoming protons and pions in the energy range 50-150 GeV with particular attention to the momentum region where a dip in the elastic scattering cross section has been seen at the ISR.

WA 7 A CERN / Genoa / LAPP Annecy/Niels Bohr Institute Copenhagen/Oslo/University College London collaboration will study two body interactions where large momentum transfer takes place. The equipment includes a CEDAR differential counter (see September issue 1975) to identify the beam particle and a hydrogen target partly in the aperture of an AEG magnet. The subsequent detectors span a wide angular range with Cherenkovs, MWPCs, and scintillation counters. Hardware processors will be used in the on-line data collection system. They will look in particular at elastic scattering and proton-antiproton annihilations which give two pions or two kaons.

WA 8 A Birmingham team will search for rare mesons coming from kaon-proton interactions. They will take a separated kaon beam, at 18 or 32 GeV, into the Omega spectrometer and will study the mass spectra of the emerging mesons in such interactions as K^+p

$\to K^+K^+K^-p$. The downstream gamma detector, as used for WA 4, will be in action to collect data on events involving a neutral pion. With incident kaons, which contain strange quarks, the mesons composed of strange quarks, such as the phi meson, will be produced more copiously. The superconducting r.f. separators, which will be used in providing the kaon beam, have not yet reached their design specification and this experiment (together with WA 13 and WA 29 which also depend on the separated beam) will not be taking data before next Summer.

WA 9 A Clermont-Ferrand / Leningrad/Lyon/Uppsala collaboration will make a high precision study of elastic scattering under conditions where the interactions involve a large contribution from the electromagnetic force as well as the strong force (the Coulomb interference region). The detection system has a hydrogen ionization chamber (described in the January issue 1975) as a recoil spectrometer and a forward spectrometer with MWPCs. They will probably be ready to receive particles in December. Measurements will be taken at several energies between 50 and 150 GeV for both particles and antiparticles.

WA 10 A Geneva/Lausanne collaboration will study kaon-proton interactions which yield particle combinations such as a neutral kaon, a pion and a proton (a V, a fast forward meson and a slow recoil proton). The detection system is magnetless, relying on time-of-flight and angle measurements done by MWPCs, scintillation counters and lead glass counters. It is almost ready to receive particles. The team will assemble a lot of data on the production and decay of bosons and baryons, including possibly some which are not yet in the charts.

WA 11 An Indiana/Saclay collaboration will search for charmed particles produced in conjunction with the J/psi particle of mass 3.1 GeV. The interpretation of J/psi as a charmed quark — charmed antiquark combination suggests that when the particle is produced, other charmed quarks could be around to form charmed mesons or baryons. The detection system is built around a large aperture magnet, called GOLIATH, containing MWPCs followed by a Cherenkov, more MWPCs, an iron filter and scintillation hodoscopes. Most of the detection system is completed and the Cherenkov is due to arrive from Saclay mid-November. The filter is used to distinguish muons (which are the only particles capable of penetrating it) and the psi particle is identified by its decay into two muons. This is another experiment of great topical interest.

WA 12 A Birmingham/CERN/Ecole Polytechnique/MPI Munich/Neuchâtel collaboration will also look for charmed particles produced in conjunction with the J/psi. They will use the Omega spectrometer fed with a negative pion beam with energies between 25 and 80 GeV. The J/psi will again be identified via its two muon decay and additional muons which may be observed could be clues to charmed mesons which have decayed. A copper absorber (after the target) and an iron absorber (at the exit of the magnet) will be added to the optical spark chambers of the Omega detection system.

WA 13 A CERN/Collège de France collaboration will use Omega to look at proton-antiproton annihilations which produce two lambdas. A separated beam of antiprotons will have energies between 5 and 10 GeV. A veto surrounds the target and a special fast coplanarity trigger system is being built with proportional chambers with their cathode planes in circular sectors.

WA 29 A Liverpool team will also study antiproton annihilations into four or six pions with a separated beam at 15 GeV into Omega. They will collect data on high momentum transfer events and try to learn whether such events become independent of energy beyond a threshold energy. They will also investigate correlations and particle multiplicities.

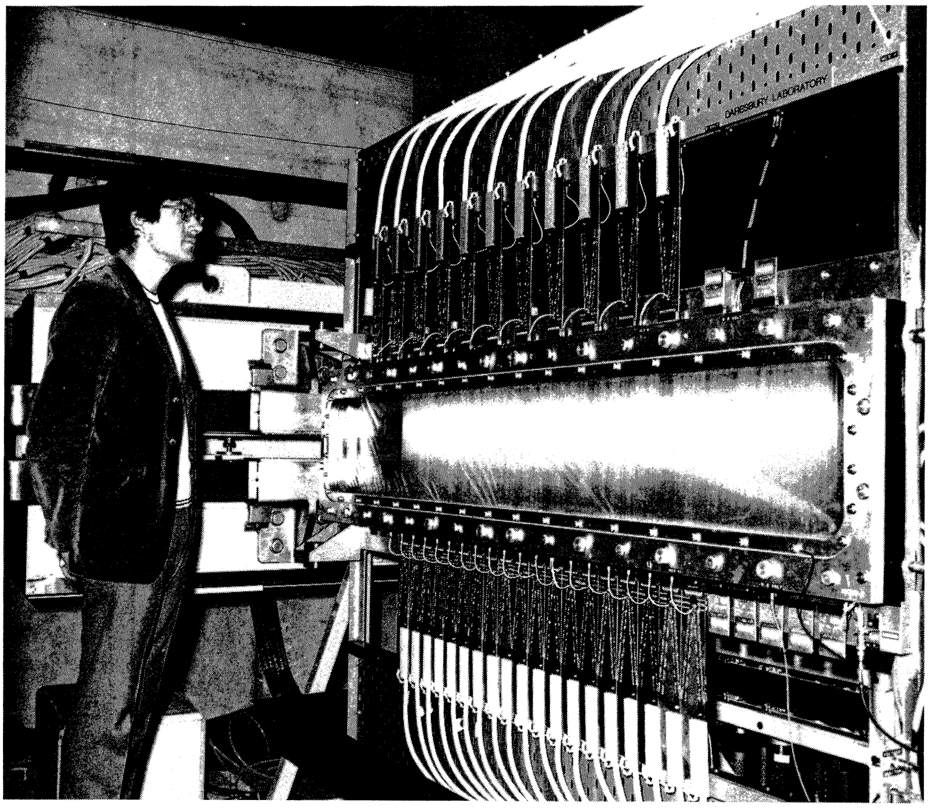
Other BEBC experiments

To conclude this review of the SPS experimental programme approved for the West Area there are three non-neutrino experiments approved for the BEBC bubble chamber using the r.f. separated beam —

WA 26 A Rutherford/Glasgow/Saclay collaboration will study negative kaon-proton interactions at 70 GeV. BEBC will be used in conjunction with an external particle identifier, EPI, and the physics is likely to concentrate particularly on interactions producing strange particles.

WA 27 A Brussels/CERN/Genova/Mons/Nijmegen/Serpukhov/Tel Aviv collaboration will study positive kaon-proton interactions again with the EPI in action. They will examine diffraction dissociation, and inclusive distributions for a range of other particles.

WA 28 An Aachen / Berlin / CERN / Cracow / Imperial College London / Vienna / Warsaw collaboration will study negative kaon-proton interactions at 110 GeV. They will examine inclusive lambda events, neutral kaon production and omega minus production and will look for charmed particles.



One of the three multiwire proportional chambers used in the photon tagging system at the Omega spectrometer. The momentum of incoming electrons, generated by SPS beams, is determined by magnets before they are directed onto a foil. The tagging system, a magnet and the MWPCs, then determines the electron momentum after the foil and the difference between the two measurements gives the momentum of the photon which is heading for the spectrometer. The MWPCs were built at Daresbury and coupled with new CERN read-out electronics. The first task of the tagged photon beam will be a search for charmed particles in very clean experimental conditions.

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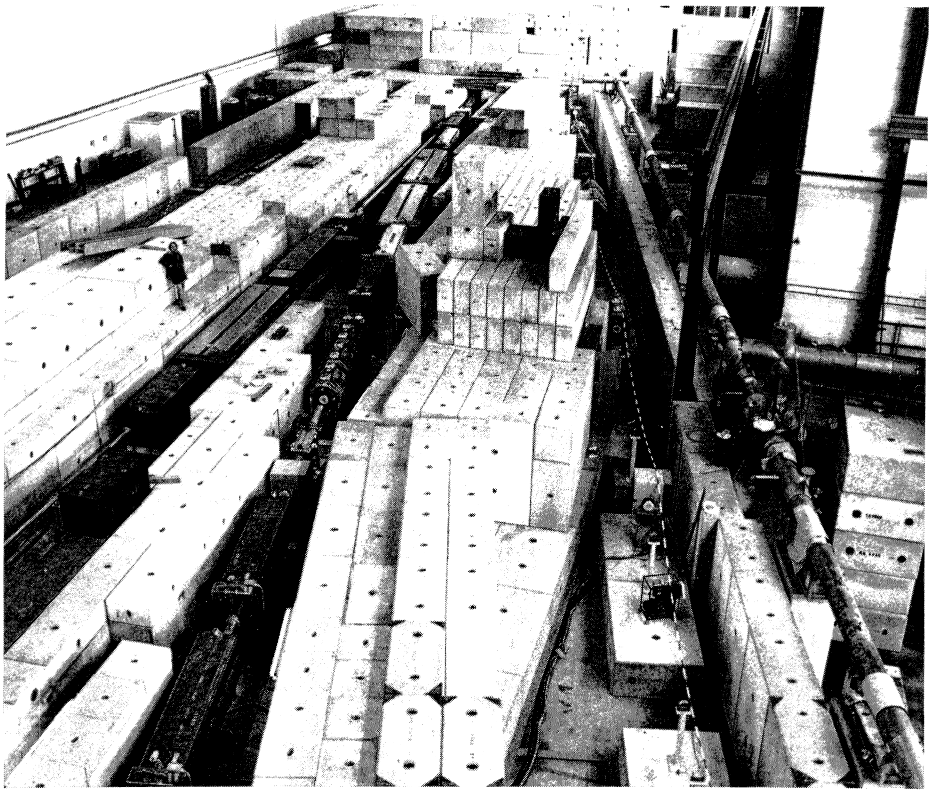


The concrete jungle of the West Hall with several beam-lines visible between the shielding blocks. In the background the mountain of blocks covers the zone where the three targets will receive 200 GeV protons. On the right, on top of the shielding blocks can be seen a pipe where liquid helium will be conveyed from a centrally located refrigerator to two superconducting r.f. separators which are scheduled for installation next year.

CERN 102.9.76

Around the Laboratories

ECFA looking to the future

In our April issue (page 128) we reported the Plenary Meeting of the European Committee for Future Accelerators, ECFA, at which it was decided to set up a Steering Group to examine the physics and technological prospects for future accelerators in Europe. The Group has been given the name ECFA Committee for Accelerator Studies, ECAS (which we hope no-one who is acronymously minded spells out).

The members of ECAS have been chosen so that both physics and machine expertise are represented. The members are — R. Billinge (CERN) and P. Lehmann (Saclay) who will have the particular responsibility of looking at fixed-target proton machines and the corresponding physics; K. Johnsen (CERN), M. Banner (Saclay) and B. Wiik (DESY) for proton-proton and electron-proton storage rings; D. Gray (Rutherford) and G. Salvini (Rome) for electron-positron storage rings. G. Von Dardel as Chairman of ECFA and F. Bonaudi representing the CERN Directorate, are also participating in the meetings.

Since the proposal to set up ECAS was put forward, there has been the important meeting at Serpukhov where all the different regions of the world involved in high energy physics were represented (see May issue, page 167 and June issue, page 210). They met to discuss the possibility of constructing a very big accelerator, VBA, as a world machine and the outcome of that meeting had important consequences for the deliberations of ECAS. It was considered in Serpukhov that the next generation of accelerators could be confronted on a regional basis and that only at a stage beyond that was a 'world machine' appropriate.

The 'lead glass wall' built at Berkeley is moved gingerly towards its location at the Stanford SPEAR electron-positron storage ring. The wall will add to the abilities of the famous magnetic detector which has unearthed the psi particles and strong candidates for charmed particles and a heavy lepton.

(Photo LBL)

In order that the idea of the world machine should not loose impetus during a regional next stage of accelerator building, the Serpukhov meeting asked the International Union of Pure and Applied Physics, IUPAP, to oversee the organization of appropriate working groups and to set up further meetings like the one at Serpukhov. IUPAP has followed up this request by initiating an Interregional Committee for Future Accelerators, ICFA. The composition of ICFA is now being discussed. It will probably comprise two members each from the USA, the Dubna Member States and Western Europe and one from Japan. A member of IUPAP will probably be Chairman.

Meanwhile the ECFA Committee for Accelerator Studies is confronted with the situation that the USA and Eastern Europe are likely to go ahead with a next generation of machines independently. However, the Serpukhov meeting did put a lot of stress on the desirability of selecting this new range of regional facilities so as to cover the broadest possible range of physics. At this stage it looks as if emphasis is being given to a fixed target proton synchrotron with an energy in the few TeV range in the Soviet Union, and to proton-proton storage rings in the 100s of GeV range in the USA (with the 200-200 GeV project, ISABELLE, proposed by Brookhaven and various possibilities at the Fermilab following construction of the Energy Doubler).

Because of this, ECAS has, initially, paid particular attention to an electron-positron storage ring with an energy up to 2×100 GeV. There has already been a preliminary look at CERN into the physics potential and the technical problems in the construction of such a machine and there is relevant expertise at DESY, where electron-positron storage rings have been built (DORIS) and are under construction (PETRA), at Rutherford, where a fully developed design study for an electron-positron storage ring (EPIC) was prepared, at Orsay where new electron-position storge rings (DCI) are coming into action and at Frascati where the ADONE storage ring is operated. In addition a study group chaired by P. Darriulat has been studying the physics potential of electron-positron storage rings of energy up to 2×100 GeV and this study group will present a report in the near future.

ECAS will be giving a preliminary report to a plenary meeting of ECFA on 25 November.

BERKELEY
Lead glass wall

At the beginning of September a large array of lead glass shower detectors and track chambers was installed at the SPEAR electron-positron storage ring at Stanford. Dubbed the 'lead glass wall', the 318 block array was designed and assembled at the Lawrence Berkeley Laboratory. After extensive tests, the array has been moved into position covering one octant of the famous SLAC/LBL magnetic detector and providing a high resolution electromagnetic calorimeter to augment the existing lead-scintillator shower counters.

The lead glass blocks are stacked in two layers to help distinguish between electron-induced and pion-induced showers. Spark chamber planes are interspersed between the layers to localize the shower with good spatial resolution.

Since early October, the new array has been in use to study inclusive electron and photon production. When coupled with the information on track position from the remainder of the magnetic detector, the collaboration

Last month we reported progress on the small superconducting accelerator/storage ring, ESCAR, being built at the Lawrence Berkeley Laboratory. The photograph shows one of the superconducting dipoles being assembled; its coil is being lowered into a stack of aluminium alloy rings. The conductor configuration can be seen on the half coil facing the camera.

(Photo LBL)

of scientists from SLAC/LBL/Hawaii/Northwestern hope to study the semileptonic decays of the newly discovered charmed particles and the leptonic decays of other new objects such as the source of the recently reported muon-electron events.

DUBNA
Thoughts on oscillating neutrinos

The concepts of symmetry and the corresponding conservation laws play a very important role in particle physics. The laws tell us which particle interactions are possible and which cannot happen. Some of them are strictly obeyed (for example, that which says that electric charge is conserved in an interaction) others are not strictly obeyed (for example, that which says that the property known as strangeness is conserved can be violated in particle decay under the influence of the weak force). In physics, as in art, the beauty of a symmetry can often be revealed more by its violation than by its being respected.

One symmetry which is being questioned in theoretical studies at Dubna and elsewhere is that of lepton charge. At present, we believe that the lepton charge is conserved — both the electron lepton charge (associated with the electron itself and the electron type neutrino) and the muon lepton charge (associated with the muon and the muon type neutrino). But there might be small violations of the lepton charge which could manifest themselves in 'neutrino oscillations' where, for example, the electron type neutrino transforms to a muon type neutrino and vice versa.

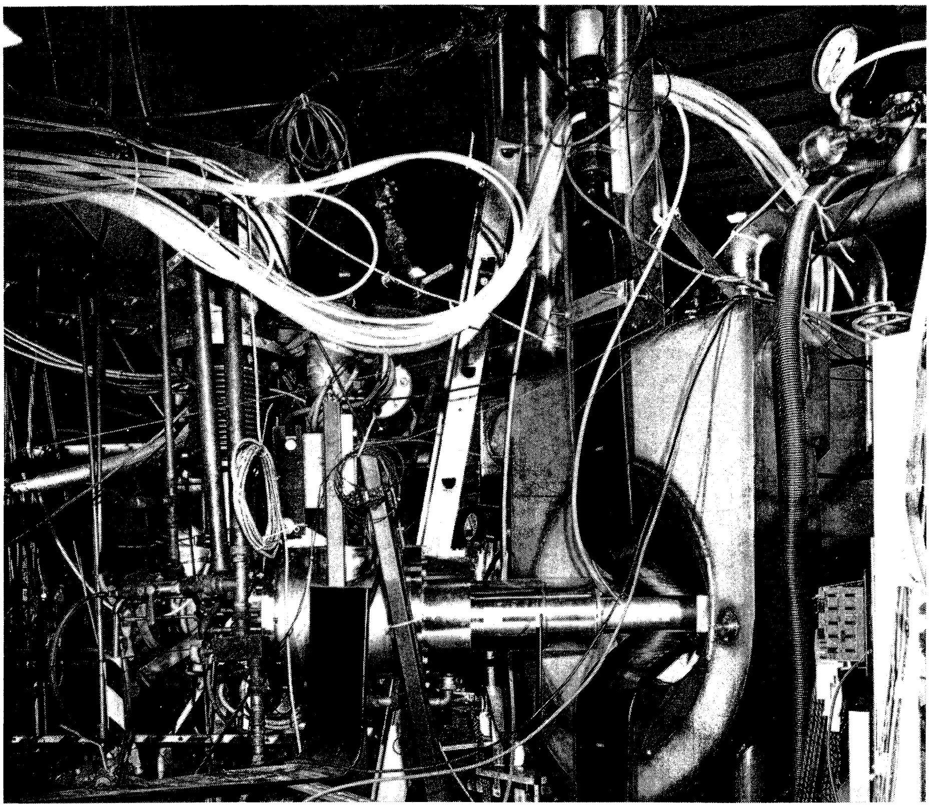
Similar oscillations are not unknown in particle physics; they are the underlying reason for aspects of the behaviour of the neutral kaon which were among the great mysteries of the 1950s. The neutral kaon showed two distinct patterns of behaviour (for example, decaying in either 10^{-7}s or 10^{-10}s) and it was realized that it is in fact a mixture of two neutral kaon states denoted K_1^0 and K_2^0. It behaves as one or the other depending upon the time at which the observation is made and oscillates between the two forms.

If the electron and muon type neutrinos were mixtures of two other neutrino states (call them ν_1 and ν_2 with masses m_1 and m_2) then it could be possible to observe oscillations where a flux of muon type neutrinos transforms into electron type neutrinos and back again. The effect would obviously be observable in principle if the distance over which an oscillation occurs (which for neutrinos of momentum 'p' is given by $2p/m_1^2\text{-}m_2^2$) is comparable to or less than the distance from the neutrino source. Observation would be easier with large distances and small neutrino momenta.

Calculations at Dubna use a parameter M_{min} which must be less than the square root of $m_1^2\text{-}m_2^2$. Oscillations of neutrinos from a reactor with momenta down to around 1 MeV, looked at over a distance of up to 1 km, would be observable with M_{min} equal to 0.05 eV. Oscillations of neutrinos from a high energy accelerator with momenta down to around 1 GeV, looked at over a distance of up to 10 km, would be observable with M_{min} equal to 0.2 eV. Oscillations of neutrinos from the sun with momenta down to 0.2 MeV, look at from a distance of 150×10^6 km, would be observable with M_{min} equal to 5×10^{-7} eV.

Remembering that the latest direct measurement of the mass of the electron type neutrino, made at ITEP

Part of the equipment used at the Argonne ZGS to measure the differences between proton-proton total cross sections in pure longitudinal spin states. The measurements were carried out at five energies between 1.2 and 2.5 GeV/c. The polarized beam, with the polarization vector rotated to lie along the beam direction, entered from the left and the polarization of the target was also aligned along the beam direction using the 'R and A' polarized target magnet. Scattered and transmitted particles were measured by downstream scintillation counters not visible in the photograph.



in Moscow gave an upper limit of 35 eV, it is clear that detection of oscillations, particularly of neutrinos from the sun, would improve neutrino mass measurements by many orders of magnitude.

However, even under very favourable conditions it is difficult to pin down the behaviour of the rarely interacting neutrinos. The best bet seems to be to detect oscillations at high energy accelerators. This might be feasible by comparing the ratio of the intensities of electron type to muon type neutrino in a beam at a fixed distance as a function of momentum. An entertaining thought is that the neutrino beam emerging from underground at the CERN SPS intersects two ridges of the Jura mountains. An intrepid experimenter might monitor the beam at CERN and at precarious locations on the mountainside.

Experiments on solar neutrinos are still fraught with too many unknowns to be hopeful in the foreseeable future, though the radiochemical technique with gallium-germanium which is being developed in the USA and USSR might improve detection efficiency. Though it may be some years before reasonable experiments become feasible, the physics involved is intriguing enough to be attracting theoretical attention.

ARGONNE
Symposium on polarization physics

The 3rd International Symposium on High Energy Physics with Polarized Beams and Polarized Targets took place at Argonne on 23-27 August. It was sponsored by the ZGS Users Group and the Argonne Universities Association and was attended by about 200 physicists of a variety of disciplines from many Laboratories around the world. There were talks by high energy theorists and experimenters working on strong, electromagnetic, and weak interactions and also by nuclear, low temperature, and accelerator physicists who have helped to make high energy polarization experiments possible.

Several exciting new physics results were presented. One of these was the discovery of unexpectedly large spin dependence in proton-proton total cross sections between 1.5 and 2 GeV/c, reported by two different groups working at the Zero Gradient Synchrotron. The data presented by each group had been obtained only days before the conference sessions. An Argonne group measured total cross section differences in pure longitudinal spin states, while a Rice/Michigan/Houston group measured them in pure transverse spin states. Each group used a polarized proton target in conjunction with the polarized proton beam.

Another new result was the evidence for a dramatic difference between the energy dependence of proton-proton elastic spin effects in the forward diffraction peak and in the large momentum transfer region (see May issue, page 177). New Fermilab results reported by two groups (one using a polarized target and one using a gas jet) show very little polarization in the diffraction peak near 100 GeV/c, while results from the ZGS and from the CERN PS show large and possibly growing spin effects in the large momentum transfer region. Other groups reported large spin effects in antiproton annihilation at CERN and in lambda production at Fermilab.

The possibility of using polarized electron beams to prove or disprove the existence of constituent quarks or partons was discussed by J. Schwinger (UCLA). Some other distinguished speakers were C.N. Yang (Stony Brook), who proposed that protons may be thought of as objects rotating with a velocity which varies with radius, F. Low (MIT), who presented a model of the Pomeron which gives very significant spin effects, L. Michel (Bures-sur-Yvette), who described a general method for analysing high energy processes in a spin-hyperspace, and H.R. Crane (Michigan), who gave a historical summary of g-2 experiments.

Many possible new ways of studying spin effects at high energy were discussed. These included polarized gas jets, polarized beam storage rings, and dilution-refrigerator polarized targets. There were also discussions of various new types of polarized targets and polarized sources for use at both proton and electron accelerators.

The social programme included a Texas style barbecue and was highlighted by a banquet at the Chicago

Art Institute. The after-dinner speaker was J.S. Kane (director of ERDA's physics research funding). He spoke on 'Trends in Basic Research in ERDA' and left the symposium participants with a feeling of cautious optimism. The scientific summary of the conference, given by Owen Chamberlain (Berkeley), produced even more optimism about seeing new and surprising spin effects in the next few years.

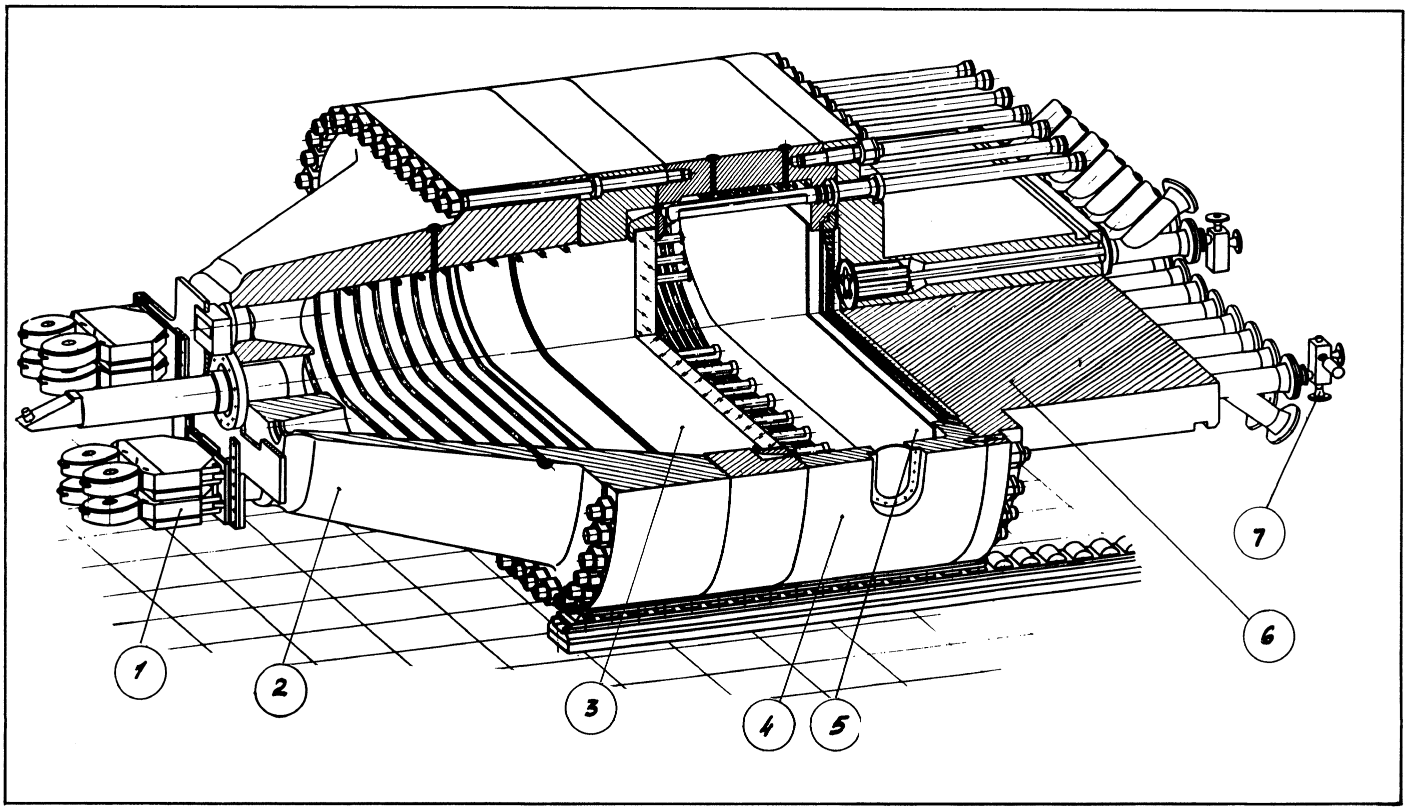
SERPUKHOV The SKAT bubble chamber

The Institute of High Energy Physics at Serpukhov has recently commissioned a large heavy liquid bubble chamber known as 'SKAT'. In many respects, this chamber is similar to the Gargamelle chamber at CERN but there are a number of important differences. This information on SKAT and its initial experimental programme was supplied by E.P. Kuznetsov.

The chamber volume is 4.5 × 1.6 × 0.95 m^3. The body is made of stainless steel with a wall thickness of 200 mm which is able to absorb a large part of the stresses produced during operation. The expansion system consists of 25 valves with an effective useful cross section of 120 mm while the electromagnetic control valves have a useful cross section of 45 mm. The time required to reduce the pressure from 25 atm to 10 atm is 45 ms and the valve operation is synchronized to within 2 ms. This system is of original design specifically for the SKAT chamber. Expansions are effected by means of a double membrane (overall thickness 12 mm) composed of a layer of reinforced resin and 'Adelite' (produced in France).

Photographs of the chamber volume are taken by four cameras fitted with special lenses. Two of them photograph the entire volume and the other two photograph half the volume; the frame dimensions are 220 × 65 mm^2 and 110 × 65 mm^2. Photographs are taken through a layer of twice-distilled water and a thick glass window, which separate the chamber liquid from the water. The window measures 4.2 × 1.2 m^2 and has a thickness of 144 mm. It is enclosed in a special surround which allows it to move ± 10 mm while still maintaining a good seal between the liquids. During the normal working cycle, the glass moves by 0.3 mm.

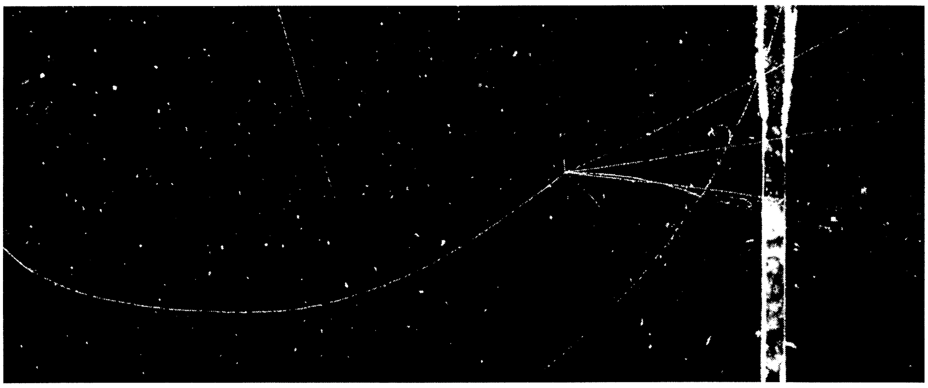
The chamber is illuminated by 27 flash units located in special housings inside the chamber volume. Their design is similar to that developed at CERN in the 1 m model chamber for BEBC. Photographs are taken with dark field illumination using a movable



Schematic diagram of the SKAT heavy liquid bubble chamber which has recently been commissioned at Serpukhov. The following components are picked out — (1) camera system, (2) water filled tank, (3) movable window, (4) volume of heavy liquid, (5) membrane by which pressure is applied, (6) main valve system, (7) control valves.

A view of the SKAT chamber in its experimental hall at Serpukhov looking from the side where the camera system is located.

1. *One of the first neutrino interactions photographed in SKAT which showed the production of a strange particle.*
2. *Another neutrino interaction where a positron has been produced.*



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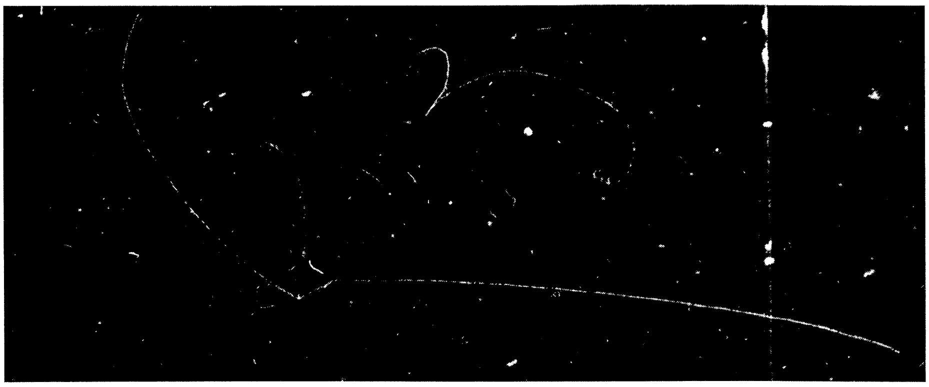

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plate with a black enamel finish. Thermal control of the operating conditions is ensured by six thermostats inserted into the chamber volume.

Certain parts of the chamber, namely the valve assembly block and the water tank, are made of magnetic steel but their configuration is such that maximum correction can be made to inhomogeneities of the field inside the chamber. The magnetic field can be taken to a maximum of 2.7 T, which requires a power of about 14 MW; for a field of 2 T, the power required is about 6 MW. The field inhomogeneity in the chamber volume does not exceed 5 %.

Commissioning of the chamber began on 27 May 1975 and, by December, the chamber was taking pictures with a neutrino beam. IHEP's neutrino beam-line is equipped with a focusing device which provides SKAT with a flux of 0.5×10^{10} neutrinos per pulse when 2×10^{12} protons per pulse are incident on the target. Under these conditions, approximately one neutrino event occurs in the chamber every 30 frames. Maximum neutrino production is achieved at an energy of between 5 and 15 GeV. In this energy range, it is planned to measure neutrino and antineutrino cross sections and to obtain data on quasi-elastic scattering and interactions with one pion production (up to a q^2 of about 5 GeV/c^2). Detailed studies will be made on deep inelastic processes and neutral current interactions, and rare processes, such as neutrino-electron scattering and associated production of electrons and strange particles etc., will be investigated.

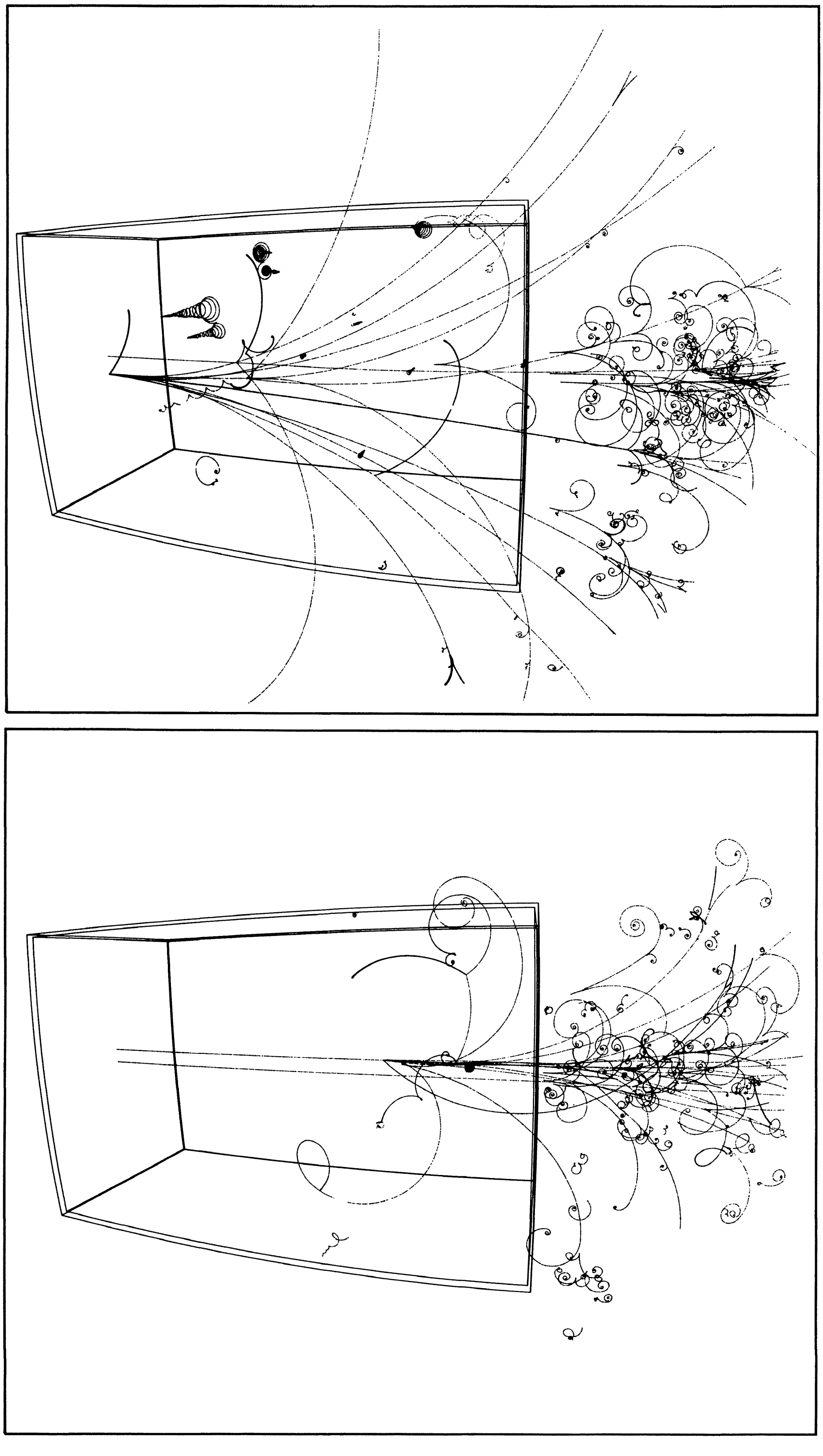
RUTHERFORD
Particles exhibit colour

Having lured people into this article by the suggestion that the postulated particle property called 'colour' has been seen, we should come down to earth quickly. Coloured tracks seen on the bubble chamber film scanning tables at the Rutherford Laboratory do not mean that colour has now been established as a new particle property. What is happening is that computer simulations have been used to investigate the efficiency with which it should be possible to detect 'prompt' electrons in the scanning process. The coloured tracks were produced to label different types of particle.

The production rates of prompt electrons and muons — events where these particles seem to come directly from hadron interactions — have been found to be much higher than was expected on the basis of conventional models of vector meson decay or direct lepton pair production. To look into this, an experiment to study prompt electrons has been proposed for the 3.7 m European bubble chamber, BEBC, with a track-sensitive hydrogen target installed and fed by a 70 GeV negative pion beam generated by the CERN SPS accelerator.

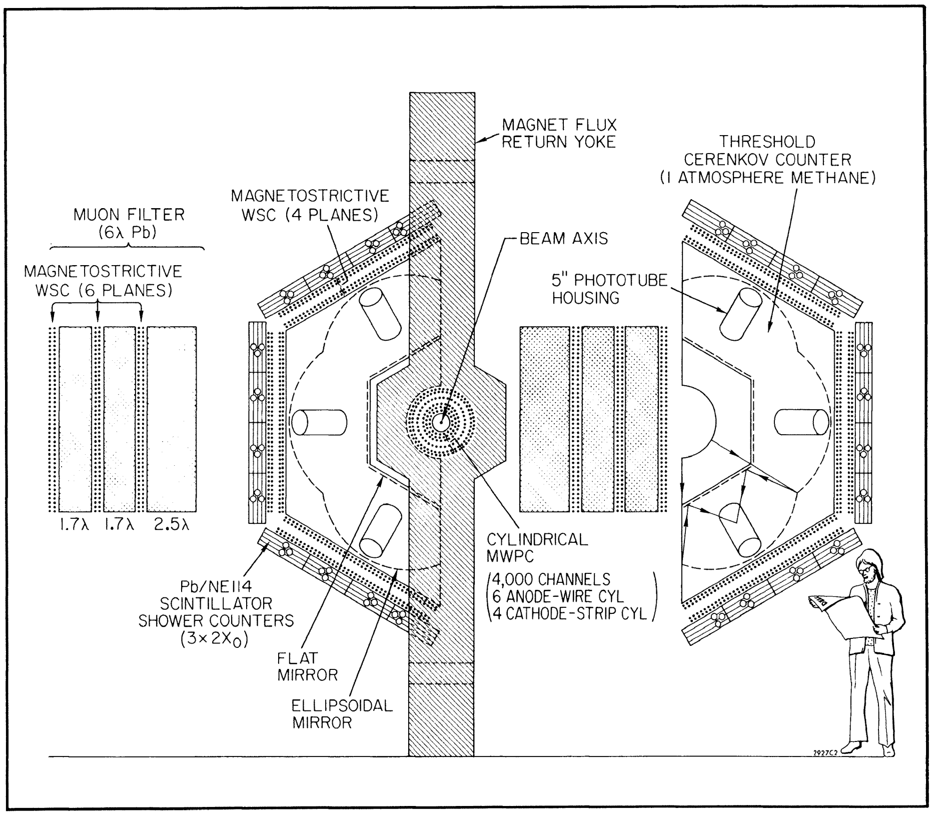
BEBC would contain a neon-hydrogen mixture in which electrons lose most of their energy by radiation, forming electron showers which enable these particles to be easily distinguished from the heavier pions, muons, etc. However, the true prompt electron events could be confused by 'background' due to spotting only one electron in a Dalitz pair or from the decay of a kaon. The background events, however, could be identified by measuring the particle tracks.

The Bubble Chamber Research Group at Rutherford has developed a computer simulation technique to produce specimen events. This will enable physicists to measure the efficiency of the bubble chamber for detecting true prompt electrons and indicate just how serious the problem



Bubble chamber events simulated by computer at the Rutherford Laboratory. They mimic events in the BEBC bubble chamber fitted with a track sensitive target (the box outlined in the pictures) to investigate how easy it will be to detect interactions giving 'prompt' electrons. A novel refinement is that the different types of particle can be made to appear in different colours.

1. Slice through the DELCO detection system which is being installed at the Stanford electron-positron storage ring, SPEAR. This shows the location of the different components at right angles to the beam directions. In the normal mode of operation, both muon filters will sit outside the Cherenkov counter as sketched on the left of the diagram.



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of background is. The technique uses a FR80 microfilm recorder — itself computer-controlled — to produce film of computer simulations of bubble chamber interactions. Preliminary results from this film show that the detection of prompt electrons in BEBC is quite feasible with a detection efficiency at about 90 %.

The programme used on the IBM 360/195 computer is divided into two parts. The first generates the positions of the 'bubbles' in space and the second projects these onto any of the five film planes. These projections are then transferred onto magnetic tape ready for input into the FR80, which in turn produces the actual 35 mm film for scanning. 'Bubbles' on some 10 000 track segments, each small enough to produce a smooth outline for the final particle trajectory, are generated for each event, which typically can produce 350 particle trajectories and 150 event vertices.

Film for a simulated 40 GeV negative pion experiment with one to three particles per burst was produced and scanned on two views. Prompt electrons were seen from Dalitz pairs and from the rho decay into an electron and positron as well as from the decay of a charmed meson of mass 2.02 GeV. The identification of these different sources of electrons was very good and the results from this computer simulation show that single prompt electrons coming from the hadron reactions can be identified with almost complete certainty. Further film was generated with a 70 GeV beam and showed little deterioration in scanning efficiency.

To check the accuracy of the scanning, a special colour film of the bubble chamber simulations was produced in which electrons show up as yellow tracks, hadrons as white, strange particles as purple and muons as blue! In this way coloured particles have been seen but not quite in the way postulated by the theoreticians.

STANFORD
PEP keeps its cool

During the Summer months a worry about heating effects of the stored electron and positron beams has been causing some sleepless nights around the PEP project of Berkeley and Stanford. The October issue of PEPNEWS reports that this worry has now been removed.

Early on in the project, it was decided to go for a high frequency r.f. system (operating at 353 MHz) taking account of klystron costs, which go down at higher frequencies, and of cavity efficiencies. At the time of the decision, consideration had been given to the heating effect of a short bunch of particles passing an irregularity (such as a recessed flange) in the vacuum chamber of the storage ring. Bench tests, coupled with experience at the SPEAR storage ring up to that point, indicated that a tolerable loss of about 5 % of the total r.f. power could be absorbed in this way, corresponding to about 300 W per metre of the chamber.

In the Spring of this year, an experience with SPEAR completely upset these calculations. A machine physics experiment, using 50 mA beams at 3.7 GeV, was cut short when the heating produced by the passing bunches burned a hole in a bellows. It became obvious that highly localized heating is produced. The effect is already uncomfortable with the beam parameters at SPEAR but it was quickly realized that the situation could be forty times worse at PEP.

The heating is proportional to the square of the circulating current and depends also on the bunch length (i.e. the r.f. frequency) and the smoothness of the vacuum vessel structure. Careful design of the vacuum vessel of PEP has probably achieved a factor of ten improvement on the SPEAR conditions but the remaining factor of four remained intractable. Lowering the beam current was avoided because it would take the luminosity (which gives the physicists their event rate per second) down with it. There remained the option of lengthening the bunches by lowering the r.f. frequency and, reluctantly, development of lower frequency cavities (about 78 MHz) was initiated.

The latest news is that a machine physics trick has taken the burden off the r.f. by enabling the beam current to be reduced without affecting the design luminosity. By operating with a vertical beta value of 11 cm in the interaction regions the same luminosity is maintained with half the current and the desired reduction by a factor of four in the heating effect is achieved. In addition, the r.f. system is required to provide less power (6 MW rather than 9 MW) and can be simplified (twelve 500 kW klystrons feeding twenty-four cavities rather than eighteen 500 kW klystrons feeding eighteen cavities at twice the power).

Every cloud has a silver lining.

DELCO detector

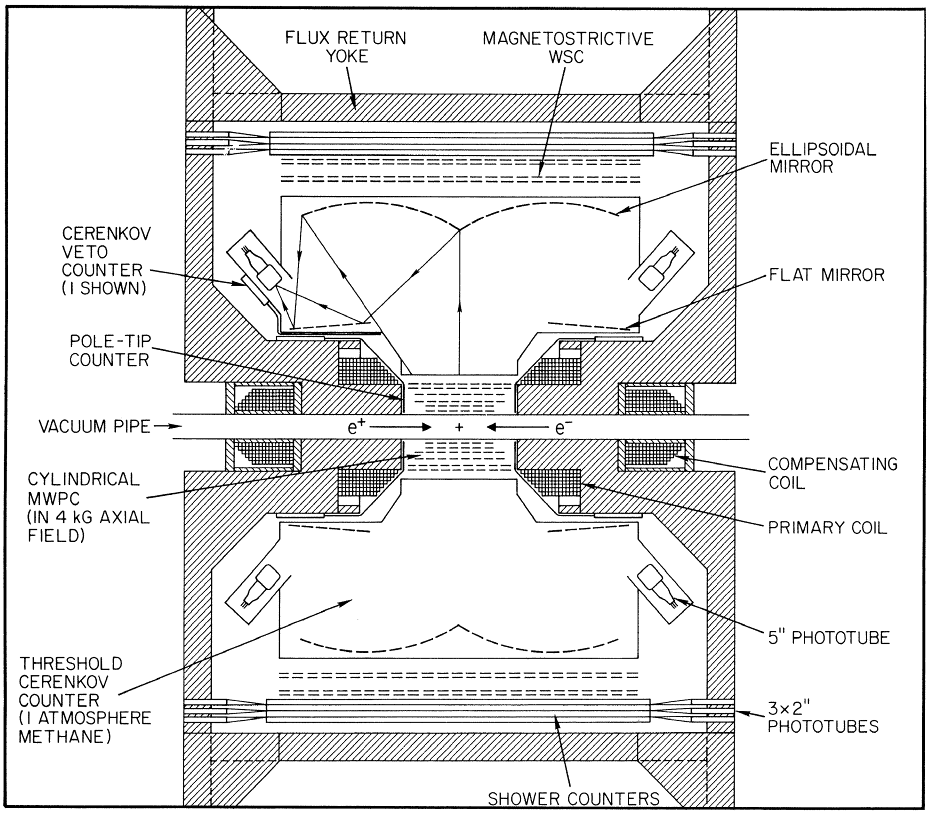
A new detector is almost ready to be installed in the East interaction region at the Stanford electron-positron storage ring, SPEAR. It is a large solid angle device which emphasizes the detection of electrons and is called DELCO (Direct Electron Counter). It has been built by a California collaboration consisting of the H. Ticho group from UCLA, the P. Condon group from UC Irvine and the M. Schwartz/S. Wojcicki group from Stanford University.

As its name suggests the detector it is designed particularly to record direct or 'prompt' electrons emerging from interactions. Such electrons have been seen at the CERN ISR and at Fermilab and are probably linked with charmed particles or heavy leptons. The study of the interactions in which they are produced is amongst the most interesting physics topics confronting us at present.

A particle, produced in the region where the electron and positron beams collide, will leave the vacuum chamber and pass through cylindrical multiwire proportional chambers (MWPC) situated in a near-axial field of 0.35 T. The field is provided by two discrete coils, located at each end of the MWPC in order to minimize the material that the particle traverses. The MWPCs (engineered by Roger Coombes at SLAC) comprise six coaxial cylindrical chambers of 3500 anode wires and four high voltage strip readout cylinders of 450 channels.

The particle then enters a one-atmosphere, methane, threshold Cherenkov counter which provides 1 m of radiator over two-thirds of the full solid angle. At SPEAR energies, the only particle which can directly emit Cherenkov light in this counter is an electron. Cherenkov light is focused by ellipsoidal mirrors which are constructed using a novel technique involving the replication of a male mould with polyester resin and glass fibre backed with flexcore hexcel and a further polyester/glass fibre layer. The resulting mirrors are of low mass, highly rigid and have an excellent focus (2 cm × 0.7 cm FWHM).

Beyond the Cherenkov cell are two magnetostrictive wire spark chamber modules which aid the momentum measurement and help identify backgrounds. Finally there is a six radiation length shower counter which helps in triggering the apparatus and provides a second tag on electrons. Over



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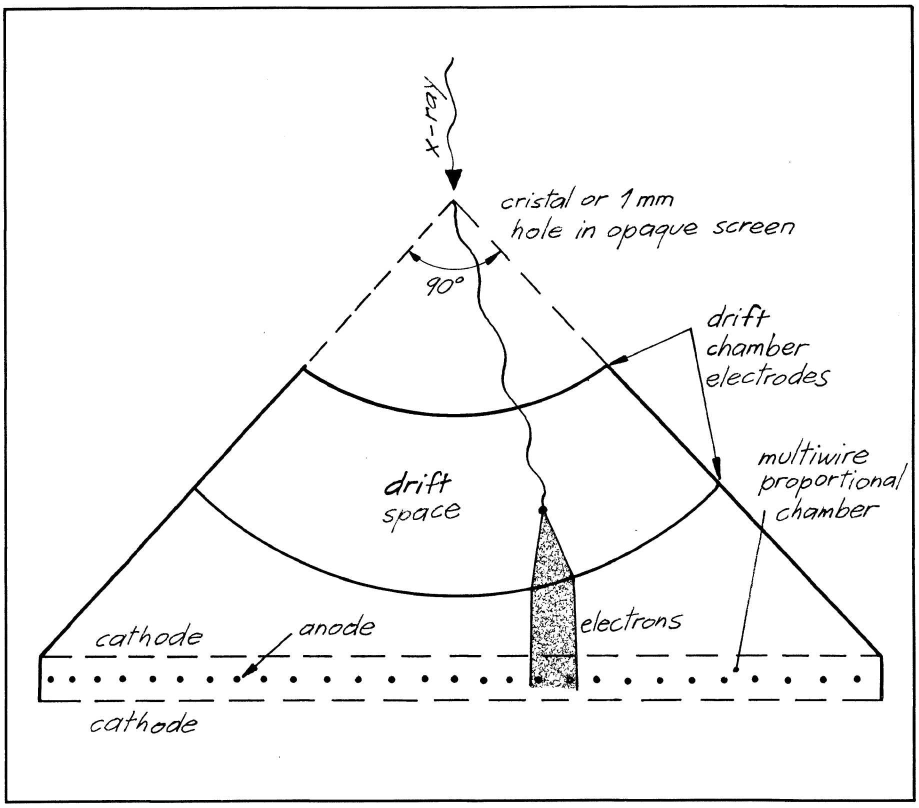
2. Another slice through DELCO, this time along the beam directions. The detection system is designed particularly to spot prompt single electrons coming from multihadron events. These electrons are almost certainly linked to the new world of phenomena — charmed particles, heavy leptons — which has been uncovered in the past few years.



Schematic diagram of the spherical drift chamber for the location of neutral particles which is giving very satisfying results in tests at CERN. An indication of its use with X-rays is sketched to show how the electron cloud initiated by the X-ray can give signals on two wires of a multiwire proportional chamber backing the drift chamber. These signals can be used to calculate the X-ray position to an accuracy better than the wire spacing by a 'centre of gravity' method.

a limited solid angle (about 6 % of 4 π) a thick lead wall is installed in order to identify muons.

The experiment will receive its first SPEAR beam in February of next year and take data through until the end of June. During that period it is hoped that DELCO will help significantly in understanding the confusing world of heavy leptons and charmed particles that is appearing at SPEAR.

CERN
Further developments of drift chambers

A more detailed understanding of what is happening in gas discharge type detectors has led to some completely unexpected advances in detection techniques in the past ten years. The advances have emerged from work at CERN since 1968 and two types of detector — the multiwire proportional chamber and the drift chamber — are in widespread use in high energy physics research and are coming into use in medical applications. Recent work, again involving a more detailed understanding of what is happening, promises still further advances and still more applications.

The mechanisms at work when a detector is operated in the proportional mode can be considered in two stages. Firstly, ionization caused by the passage of a charged particle between anode and cathode planes of wires, liberates electrons which 'drift' towards the nearest anode wire under the influence of the electric field. Secondly, in the immediate vicinity of a wire, where the field gradient is higher, the electron gains enough energy to cause further ionization. In the last few path lengths an avalanche of electrons is built up and is swallowed by the anode wire. The ions left in their wake head for the cathode plane and it is the negative pulse that they induce as they traverse the high field gradient region near the wire that is the major contribution to the signal from the anode wire. In addition, the ions give a positive pulse to neighbouring wires so that the wire nearest to the position where the particle crossed the chamber is easily distinguished. This is the technique of the multiwire proportional chamber (MWPC).

The signal from an anode wire gives one spatial coordinate of the particle. A second coordinate can be obtained by recording the ions arriving at the cathode plane which can be wires or strips. The ions tend to spread out as they traverse the chamber and it is the 'centre of gravity' of the anode signal which is taken as the coordinate measurement. Techniques for reading the second coordinate have been developed particularly at Berkeley and Oak Ridge.

A different use of the mechanisms at work is to measure the time taken for the electrons to drift to the anode wire. Using a scintillation counter to pin down the time of arrival of a charged particle to a nanosecond, the time taken for the electrons to reach the nearest wire can be measured and this makes it possible to determine a spatial coordinate to about 100 μm. This is the technique of the drift chamber which has been applied in a variety of ways at many Laboratories such as DESY, Harvard, Heidelberg, Saclay. . .

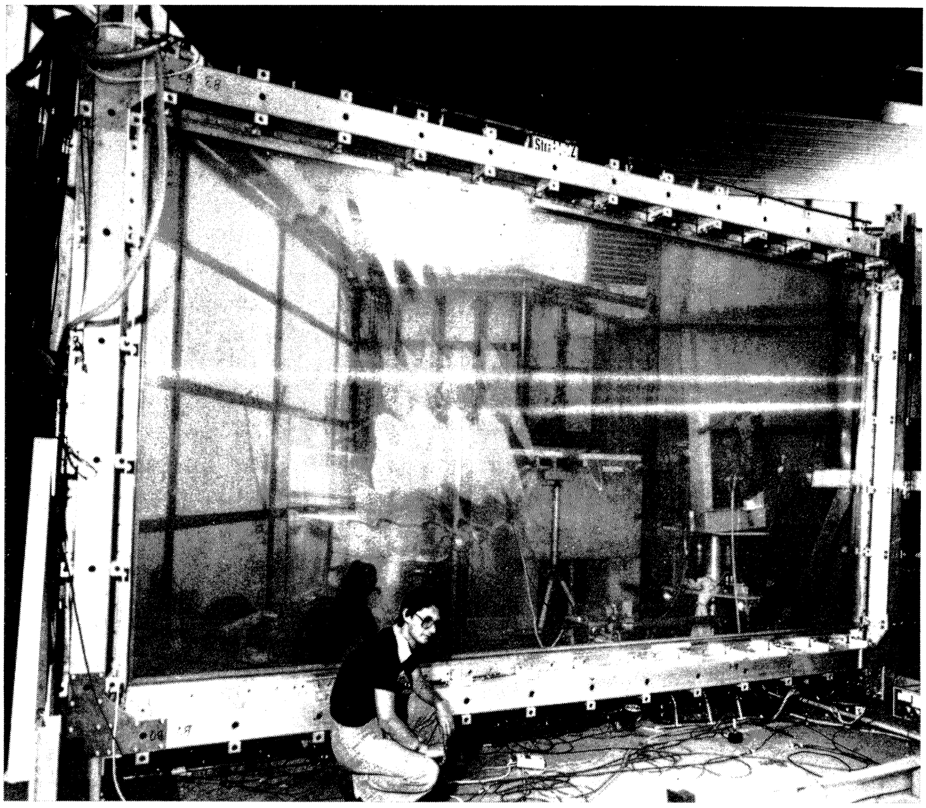
Some of the recent work at CERN has concentrated on a chamber for the detection of neutral particles. Once a neutral particle initiates a charged particle by collision with a gas molecule within the chamber volume, its position in two coordinates can be extracted. This is a great advantage with low energy particles which have not enough energy to emerge for further observation in a second detector. Medical applications with X-rays and gammas will be of great importance.

The CERN detector (worked on by G. Charpak, C. Demierre, R. Kahn, J.C. Santiard and F. Sauli with help from A. Breskin, R. Bouclier) adds a drift region to a MWPC, as shown in the diagram, to increase the efficiency in X-ray detection. If the X-ray is not travelling parallel to the electric field in the drift region it can liberate electrons at several positions along its path giving signals on several wires and blurring the information as to its true direction.

A neat way out of this has been to build the drift chamber region like a piece out of a sphere with the field lines radiating out from the point where the specimen being X-rayed is located. A scattered X-ray then travels along a field line and liberated electrons head for the same wire. (R. Benoit and N. Greguric did some clever work in the mechanical construction of this 'Spherical drift chamber'.)

The interesting realization in the past few months has been that because of the diffusion in the drift space, the electron cloud can fan out to give a signal to two wires. Using a 'centre of gravity' approach on these two readings, the location of the initial electron can be calculated to give a spatial resolution better than the wire spacing. Because of this it was possible to go from 1 mm wire spacing, which was causing mechanical problems, to 2 mm wire spacing and to achieve coordinate measurements to better than 1 mm.

The important fact is that it is possible to position particles to better than the distance between the wires, provided the electrons can drift far enough to spread the electron cloud. In addition, having a long drift region allows a higher amplification to be achieved than in a thin proportional counter. The disadvantages are that the counting rate may be lower since longer lengths of wire are 'deadened' by every pulse. Also the electronics necessary to do the centre of gravity sums will be more expensive. However, the advantages are considerable and it should not be difficult to construct large chambers with anode wires of 20 μm diameter and 2 mm wire spacing.



Prototype of a large drift chamber which has been tested at DESY. Excellent results have been obtained. Sixteen such chambers are to be built for a muon experiment at the SPS.

(Photo DESY)

DESY
Drift chambers for the SPS

A large drift chamber, which is a full size prototype of a series of chambers with a total of sixteen signal wire planes, has been built and successfully tested at DESY. The chambers will be part of the forward spectrometer which is being built by the European Muon Collaboration and CERN to study muon scattering using a 300 GeV muon beam in the SPS North Area.

A fascinating programme of physics is envisaged for this spectrometer since very energetic and very heavy virtual photons will be available to probe the quark structure of the nucleons and to produce new particles. To be able to do this, the particles emerging from the interactions with high momenta have to be analyzed very accurately. Drift chambers are the best type of detector for this job since they allow space coordinates of high energy charged particles to be measured with high precision.

The prototype chamber has a useful area of 2.5 × 5.1 m^2. It consists of two planes with signal and potential wires and three cathode planes. The size of the drift cell is 2 × 2 cm^2 (measured from signal to potential wire and from cathode plane to cathode plane). The cathode planes have wires spanned across the short dimension with 2 mm wire distance. Signal wires and potential wires are spanned in three different directions, the longest ones horizontally, with a length of 510 cm.

The cathode planes are at earth potential. A gas mixture of argon, methane and isobutane was found to give good results (argon with isobutane alone was not satisfactory because of the rather large variation of the electrical field across the 2 cm drift space with constant cathode potential). The mixture gave an efficiency around 99 % with deviations from linearity below half a millimeter. The resolution of the space coordinate was found to be almost as good as for small chambers. For the shorter wires it is 0.17 mm and for the 510 cm wires, 0.21 mm. It has thus been demonstrated that good spatial resolution can be obtained also for large drift chambers.

The mechanical construction is very rigid, with very accurate positioning of the signal and potential wires, in order to maintain the measurement precision. Also, a very dense packaging of many planes is possible. The sixteen planes required for the experiment can be put together to occupy only 41 cm in depth.

Production of the final chambers has started at the DESY Laboratory and it is expected that they will all be in place at CERN by the end of 1977.

LOS ALAMOS
New neutron sources

The Los Alamos Scientific Laboratory is building facilities for research with neutron beams which are at present unparallelled anywhere in the world. A Weapons Neutron Research Facility (WNR) is scheduled for operation early 1977. An Intense Neutron Source (INS) saw approval of an environmental impact statement and the start of some coring for construction at the beginning of this year.

The WNR draws its beams from the 800 MeV proton linear accelerator, LAMPF. A chopper in the LAMPF injector separates the tail of the proton pulse so that a kicker magnet can deflect the protons in the tail to the WNR while the main pulse continues towards the LAMPF targets for use in the meson physics research programme, etc. The deflected protons reach the WNR at a rate of 120 Hz and the duration of each pulse can be adjusted from nanoseconds to microseconds. This ability to use short bursts of particles is a special feature of the WNR.

The protons produce neutrons, at a rate of about 12 per incident proton, by spallation in a tungsten target (a cylinder 2 to 4 cm diameter, 15 cm long). The neutrons emerge with energies from about 30 MeV to 10 keV (the lower energy spectrum can be extended down to 0.03 eV by using a moderator around the target). Many beam tubes fan out from the target room to allow neutrons through to the experiments. A second target room can be used for scattering neutrons or for receiving low intensity proton pulses.

To extend the abilities of the WNR in the future, a proton storage ring is being designed. It would stack many proton pulses and compress them into a bunch so that a very short, very high intensity pulse of neutrons could be generated by firing the proton bunch from the storage ring at a target.

The INS is budgeted at \$25 million and is scheduled for completion in 1980. It is intended as a neutron factory, in the same way that LAMPF is a meson factory, capable of supporting a broad research programme involving many experimenters.

Neutrons will be generated in a supersonic deuterium gas jet intersected by a beam of tritium ions yielding a flux of 10^{15} neutrons per second at an energy of 14 MeV. Two identical reaction chambers of this type are envisaged.

The INS is at the stage of detailed engineering. Components, such as the ion source which is required to yield 1 A of tritium ions, are under development. Much of the experimental programme (neutron cross section measurements in a variety of materials, materials damage investigations in intense neutron fluxes) will be directly relevant to fusion reactors since the reactors will experience the identical bombardment with 14 MeV neutrons.

FERMILAB
Cancer Therapy Facility treats first patient

On 7 September a dose of neutrons was administered for the first time to a volunteer patient at the Fermilab Cancer Therapy Facility. The patient, a woman suffering from recurrent cancer of the tongue, spent about an hour at the Facility and has since returned several times to receive further doses.

Miguel Awschalom, Deputy Head of the CTF, reports that the commissioning of the Facility was 'satisfactorily smooth'. The achievement follows several years of planning, research, and construction by Fermilab staff members and a number of members of the medical community in the Chicago area. Trials with patients will continue as more collimators necessary to irradiate different types of tumour become operable. A three day per week irradiation schedule is now in effect and will soon become five days per week.

All patients will be referred to

Alan Jones, a technician at the Fermilab Cancer Therapy Facility, positions his head at the neutron beam port. The first irradiation of a patient took place at the Facility in September.

(Photo Fermilab)

Fermilab by radiotherapists from participating medical institutions. Not all cancers are suitable for neutron therapy and the decision to use neutron radiation will be made in accordance with protocols established nationally by the Radiation Therapy Oncology Group. Only carefully selected patients will be irradiated. Certain tumours of the mouth and upper respiratory passages, advanced cancers of the cervix, prostate, and some brain tumours, which resist conventional treatments, are being treated experimentally at the four fast neutron installations in the USA. Some cancers of the lung and pancreas, as well as certain bone and soft tissue malignancies, will be irradiated in conjunction with chemotherapy.

Fast neutrons for the CTF are generated by protons from the linac which are available when the main ring is going through its acceleration cycle. Protons are thus available for about 70 % of the time during every accelerator pulse. A pulsed and a d.c. magnet installed after the fourth linac cavity, deflect a 66 MeV proton beam 90° to a beryllium target. The collisions produce the fast neutron beam.

A portion of the long gallery parallel to the linac has been remodelled to create the Cancer Therapy Facility. It contains rooms for patient reception, the control room and treatment area. The heavily shielded treatment area surrounds a former linac freight elevator so that patients can be lowered from the linac gallery at ground level to the floor below on a level with the linac. No long-term patient care is provided at Fermilab and only ambulatory patients are accepted.

It has been known for many years that oxygen-poor or anoxic cells tend to be more radiation resistant than normal cells and rapidly multiplying cancers, which often outgrow their blood supply, result in anoxic cells. Research at the Hammersmith Hospital in England and elsewhere has indicated that anoxic cells may be less resistive to fast neutron irradiation than to X-rays. Large scale clinical trials under controlled conditions are necessary to confirm the research work and the Fermilab CTF has been constructed with this in mind.

As with X-ray treatment, fast neutron therapy uses a series of partial exposures or fractions. The average patient irradiation will last about four minutes with about twenty minutes for preparation. A typical treatment will require twelve to twenty-eight exposures. The CTF could probably do two to four patient fractions per hour.

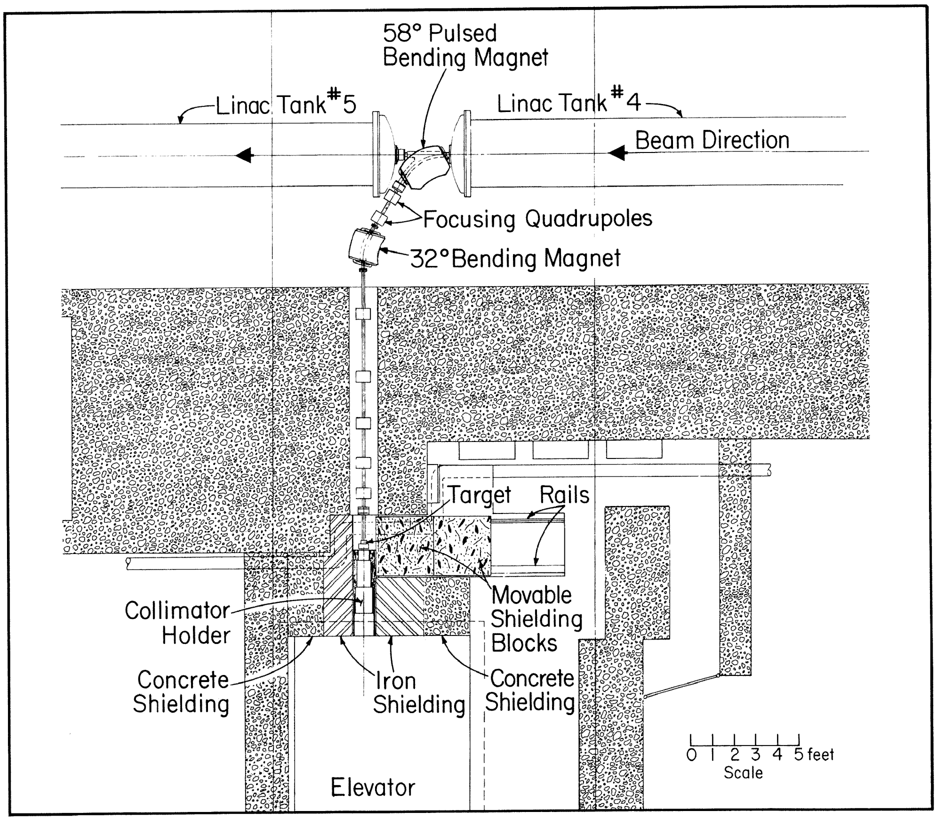
It is expected that about 300 to 600 patients will go to the CTF in the first year. In the Chicago area, some 11 000 people are victims of cancer each year and about 1000 of these cancers may be treatable at the CTF. Patients from anywhere in the United States may also be referred to the Fermilab.

The possibility of using high energy protons for radiation therapy was suggested in 1947 by Bob Wilson. With the construction of the linac at Fermilab, discussion started on the multiple use of the accelerator for medical purposes. Initially, the ideas turned to the direct application of the proton beam for therapy but as the discussions continued, interest in the possibility of fast neutrons developed. An ambitious plan was devised for a large facility detached from the linac gallery. Later, the present facility was proposed since it is of such a scale that funding could be found much more readily.

Design began in January 1975 and the first neutron beam was achieved in July of that year. Through to January 1976, measurements were made of the physical and radiobiological properties of the beam and these data permitted design of the final shielding and improved controls. Other studies measured the dose distribution in tissue-equivalent phantoms. Six groups of radiobiologists measured the effects of different neutron doses on bacteria, mice, tissue cultures, and other biological systems.

The CTF will function as the Cancer Therapy Department of the Accelerator Division. Lionel Cohen, a radiotherapist who is Head of the Department of Radiation Oncology at Michael Reese Hospital Chicago, heads the Department staff. Other members include Frank Hendrickson, M.D., Head of the Department of Radiation Therapy at Chicago's Presbyterian-St. Luke's Hospital. Miguel Awschalom, who joined Fermilab in 1967 to design radiation shielding and look after radiation protection, is Deputy Head. Don Young, who joined Fermilab in 1967 to head the team that designed and built the 200 MeV linac is Associate Head. Also Ivan

Layout of the Cancer Therapy Facility at Fermilab. A 66 MeV proton beam is taken off after tank 4 of the linac and fired at a target to produce neutrons for cancer therapy.



Rosenberg, a medical physicist, has recently been appointed to the project.

The National Cancer Institute (US Department of Health, Education, and Welfare) has made a grant of $816 000 for three-year operating funds for the CTF, beginning 30 June 1975. The Laboratory's prime sponsor, the United States Energy Research and Development Administration (ERDA) has helped significantly in making the new facility possible.

Through the efforts of the medical profession in the Chicago area, private funds have also been contributed for modifying the building to accommodate the new facility, and for some equipment. The Field Foundation has donated $50 000, the Joyce Foundation $50 000, the A.B. Dick Company $5000, the Chicago Community Trust (through Harry L. and Elizabeth Marshall, Dr. Adolph Gehrmann, and the William Allen Pusey Fund) $50 000, Elliott Donnelley $10 000, Chauncy and Marion McCormick Charitable Fund $10 000, Robert R. McCormick Charitable Trust $50 000, Amoco Foundation $10 000, Metropolitan Association of Radiation Therapists $106. Patients will pay the referring institutions for their normal services but Fermilab will make no charge for the neutron irradiations under the terms of its NCI grant.

As we close this issue we learn of the award of the 1976 Nobel Prize for Physics to Burt Richter and Sam Ting. Our congratulations to these two fine scientists. We shall be celebrating their award in our next issue.

People and things

Conference organizer extraordinary

At the end of September, Miss Steel retired from CERN after over 20 years as a staff member. It was as an organizer of Conferences that she became well known throughout the world of high energy physics. From 1956 to 1971 she led the Secretariat for Rochester Conferences, International Accelerator Conferences, European Elementary Particle Physics Conferences, CERN Schools, etc. . . both at CERN and at other Laboratories in Europe. She was also called upon to advise on the organization of some Conferences in the USA. Her accumulated experience was second to none and her hard work ensured that it was always at the service of high energy physics. She carries with her the respect and appreciation of a whole community of physicists.

Radiobiological Review

In recent years we have frequently carried news on medical applications of beams of accelerated particles. (The start of irradiations at Fermilab is mentioned in this issue.) At the Rutherford Laboratory they have concentrated on the use of negative pion beams, generated by the Nimrod synchrotron, in radiobiology. A good review of their research during the years 1971–1976 has just been issued, edited by R.E. Ellis, P.J. Lindop, J.E. Coggle and G. Fraser. The report number is RL-76-092.

Dubna 20th anniversary

The Joint Institute for Nuclear Research at Dubna is celebrating its 20th anniversary and a book 'Dubna 1956–1976' has been published, containing many of the excellent human photographs of Yu. Tumanov.

Dubna is celebrating its 20th anniversary. Typifying the many international collaborations in which the Institute has taken part, this photograph from 1972 shows Professor Jentschke on the left, then Director General of CERN, examining bubble chamber pictures with Professor Dzhelepov, Head of the Dubna Laboratory of Nuclear Problems. Altogether these two scientists had the backing of 24 countries.

(Photo Yu. Tumanov, Dubna)

Group photo of Soviet scientists with US officials and their Stanford hosts taken during a visit to SLAC. The line up reads, left to right back row: O.M. Rodzianko (US translator), V.A. Yarba, V. Matveev, J. S. Coleman (ERDA), L. Keller (SLAC). Front row: D.F. Khokhlova, P.A. Cherenkov, W.K.H. Panofsky (SLAC), I.V. Chuvilo (Head of Delegation), V.A. Vasilyev, A.Ts. Amatuni, V.F. Kuleshov. The visitors attended a conference on US-USSR cooperation in science, after which they visited American laboratories including Berkeley, Stanford, Fermilab and Brookhaven.

(Photo SLAC)

Dubna itself is a multinational organization (with Albania, Bulgaria, China, Czechoslovakia, German Democratic Republic, Hungary, Korean Democratic Republic, Mongolia, Poland, Rumania, Vietnam and USSR as its founder Member States) and has been prominent in the broad international collaborations in high energy and nuclear physics. (One of these collaborations, with CERN, is picked out in the photograph.) During its twenty years of existence Dubna has grown from a staff of 1300 to over 6000. They have operated a proton synchrotron, a synchrocyclotron, heavy ion accelerators, nuclear reactors and the necessary detection systems for research at these facilities. There has been some fine experimental work, particularly on heavy elements, backed up by a theoretical group of world standing.

Bicentennial particle

The August issue of the excellent journal of the Stanford Linear Accelerator Center, 'SLAC Beam Line', spotted that SLAC Publication Number 1776 announced the discovery of the charmed particle of mass 1876 MeV in July 1976.

Boosting the Booster

A report from the staff working on the CERN 800 MeV four-ringed Booster was given at the 5th All Union National Conference on Particle Accelerators in Dubna on 5–7 October. It announced a peak intensity of 1.3 × 10^{13} protons per pulse and the remarkable reliability of 98.5 % of scheduled operating time. Work is under way on increasing the intensity towards 2 × 10^{13} and on decreasing the cycle time towards 0.6 s from 1.2 s. Machine physics experiments are also being made to add bunches vertically

The storage ring operators and experimental physicists at the Stanford SPEAR storage ring have been having some fruitful fun during the Summer months improving the operating and detection efficiencies. A palm frond was awarded to the team which clocked up the largest number of detected and analysed multi-hadron events in a single shift. This competition led to a tightening of routines for injection, tape-changing, counter checks, etc. . . and to muttered expletives at such things as typing errors in reloading programs which could lose five minutes in the attempt at a new record. In the picture, the then holders of the record had gathered 807 hadron events at 4.028 GeV centre of mass energy in one shift.

from two of the rings rather than to eject from the rings sequentially. The doubling in longitudinal density thus achieved would increase luminosity in colliding beam experiments and could make proton-antiproton options more attractive.

Particle physics and Eastern philosophy

An unusual book about our research was published by Macmillan at the end of September. Its title is 'The Fabric of the Universe' and the author is Denis Postle a self-proclaimed 'lay man' who became fascinated by particle physics while producing a BBC/CERN film, 'Shadows of Bliss' a few years ago. A central theme of the book is that the knowledge emerging from our research is in line with the interpretation of the Universe which is at the heart of Eastern philosophy. It is a very individual view of particle physics which is presented in readable style in an attractively produced book.

Element 107

A team led by G.N. Flerov at Dubna has synthesised element 107. They used a 290 MeV beam of chromium ions onto a bismuth target and saw results which corresponded to the alpha decay of element 107 (with a nucleus of 107 protons and 154 neutrons) followed by the fission of element 105 which is thus produced.

1.

2.

A lively Fermilab tradition is the canoe race around the cooling water canal which traces the circumference of the main ring. The 4 mile race including 17 portages around the dikes, was won this year in a record time of 45 minutes, 19 seconds, by a USA/Canada collaboration:
1. John Cumalat (left) of Santa Barbara and George Luste of University of Toronto.
2. Last year's winners Jim Prentice (left) and John Martin, both from Toronto, were second.

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	mod.	6011	Discriminator
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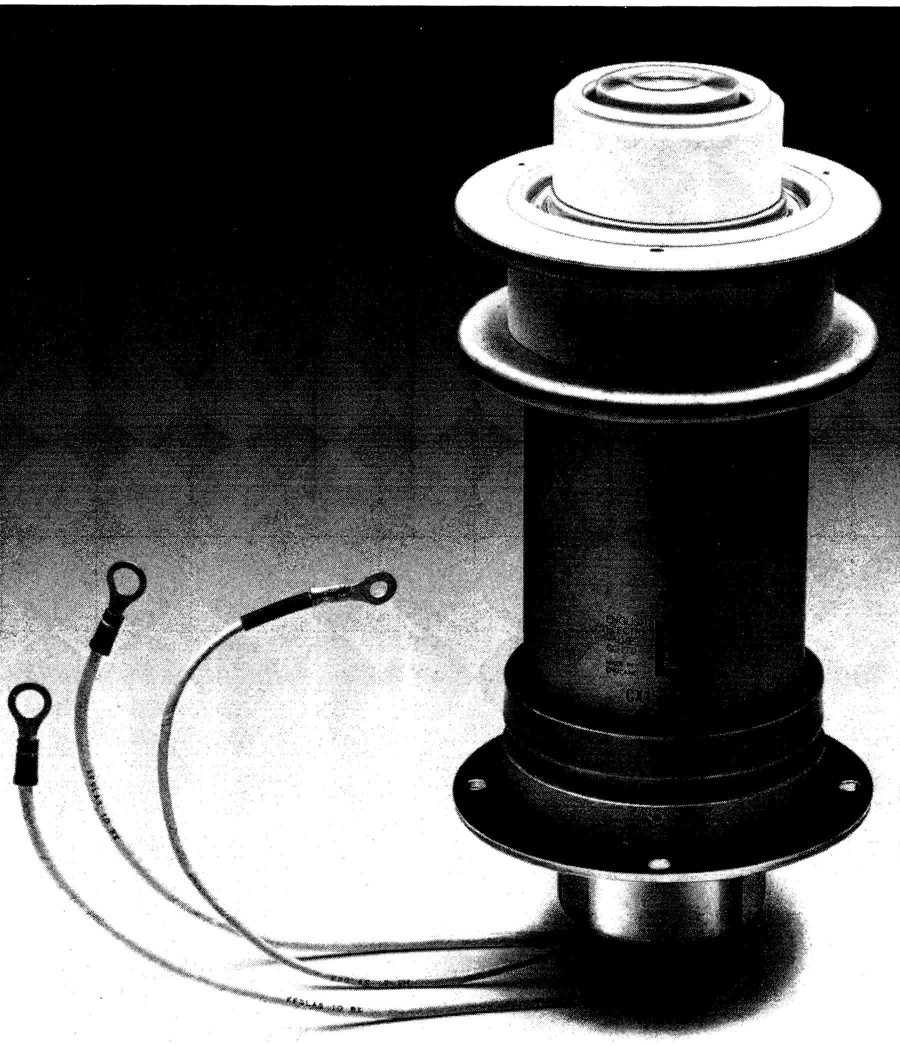

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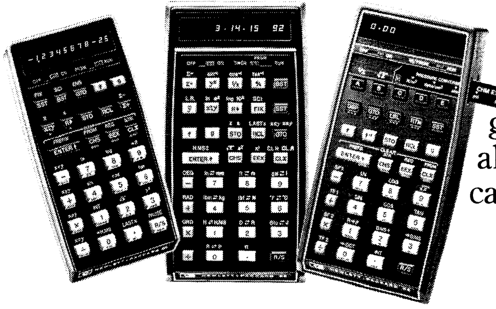

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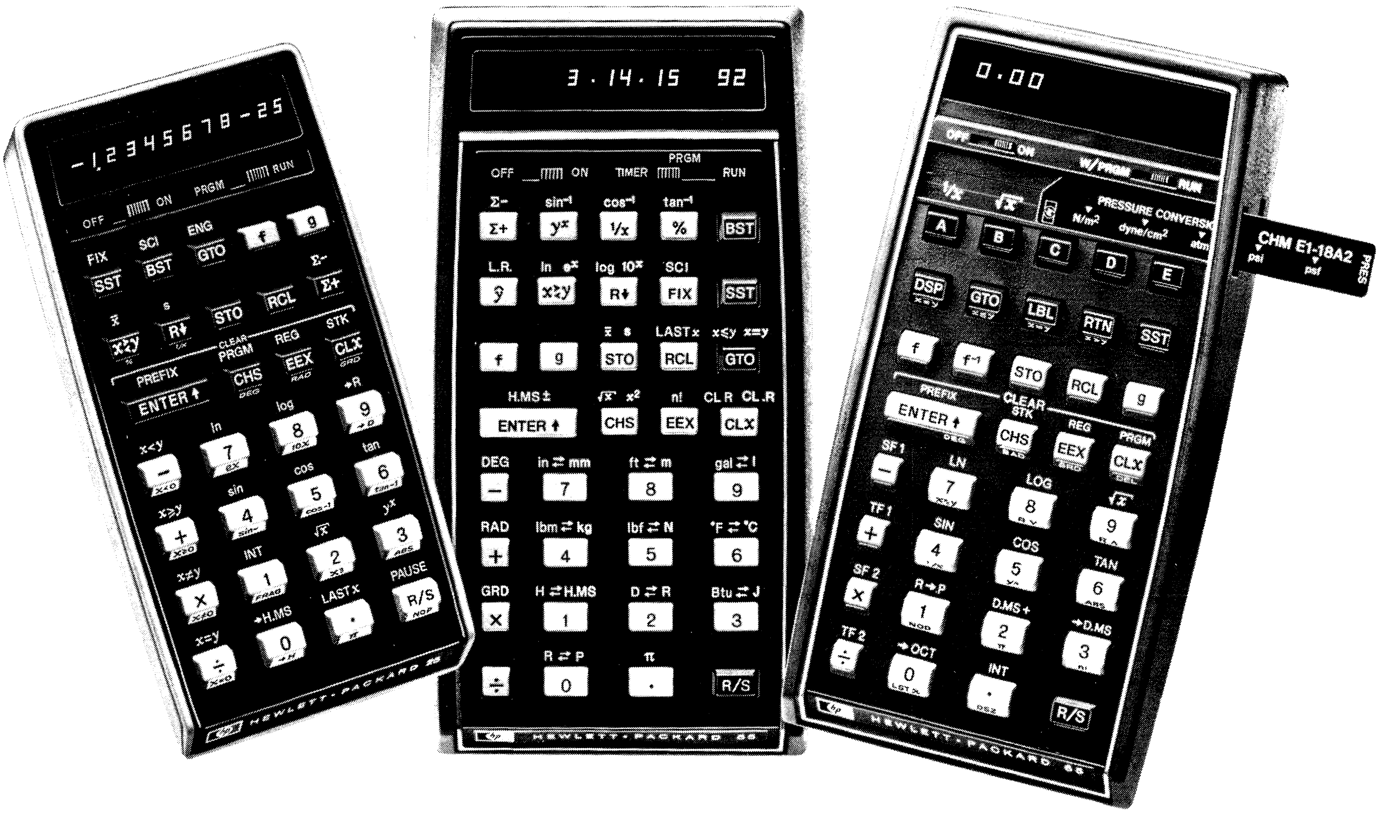

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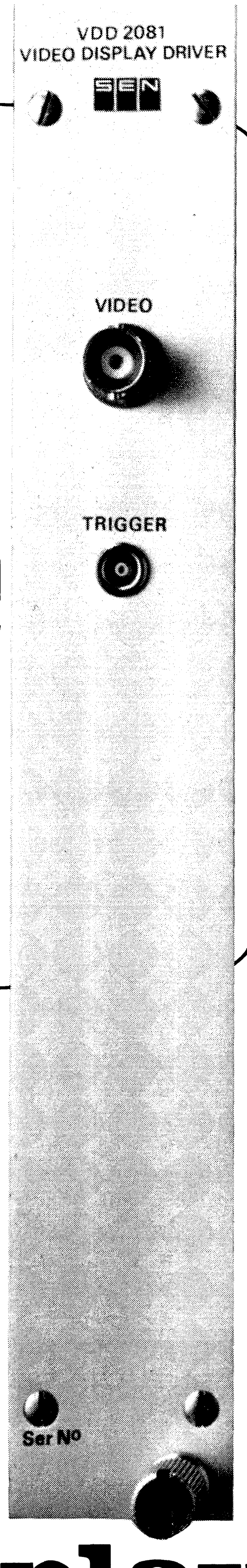
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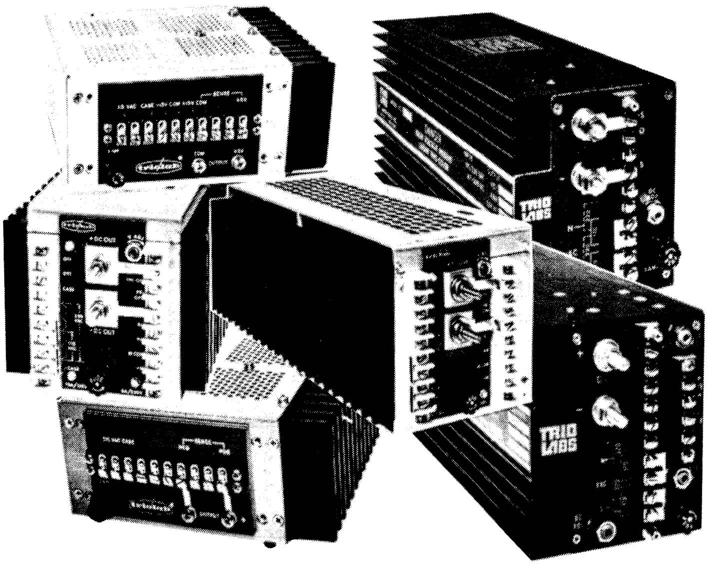

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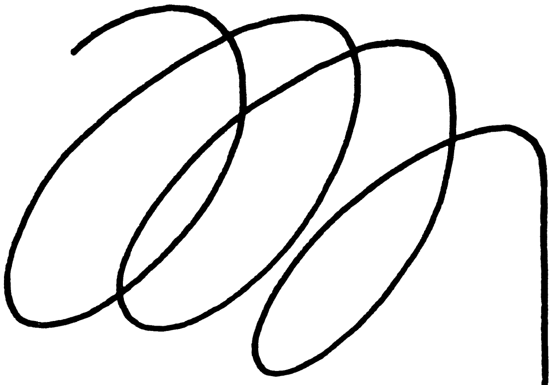

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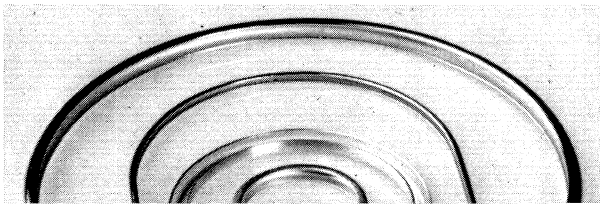

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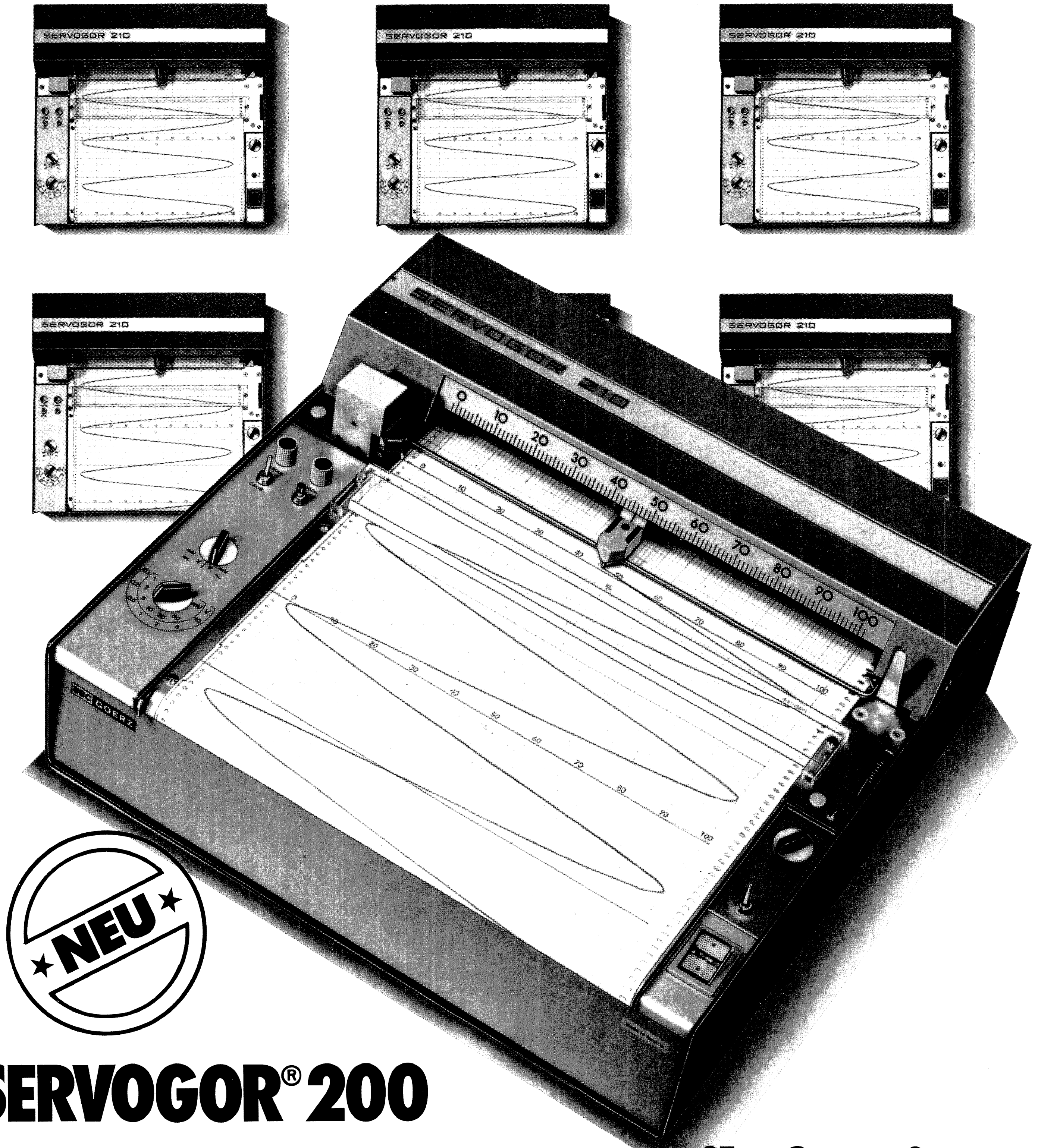
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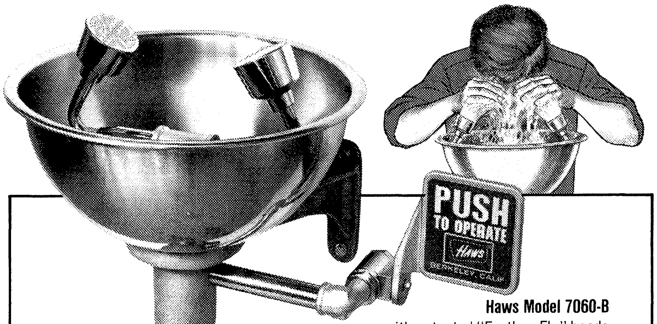
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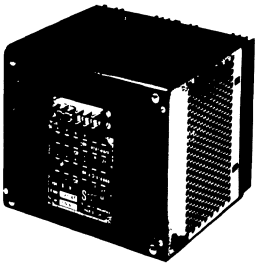

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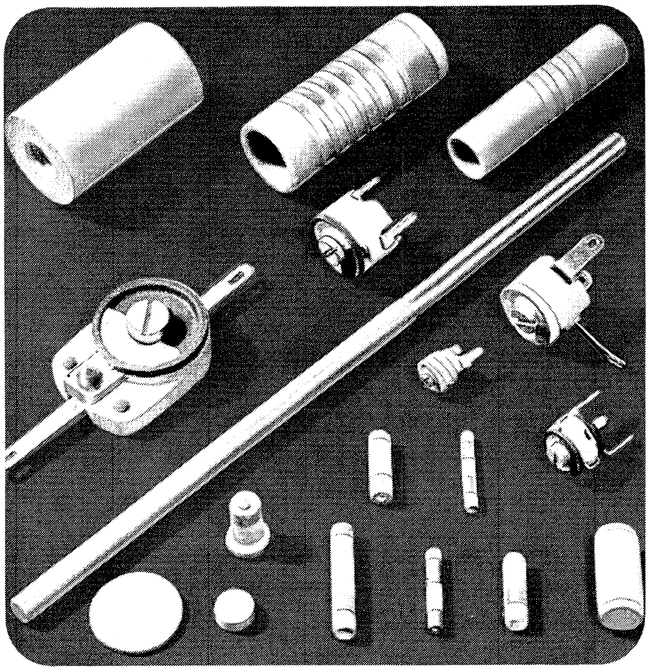

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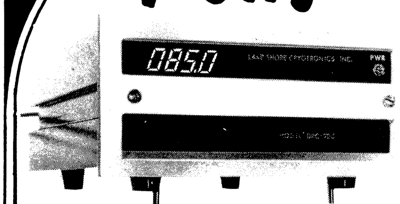

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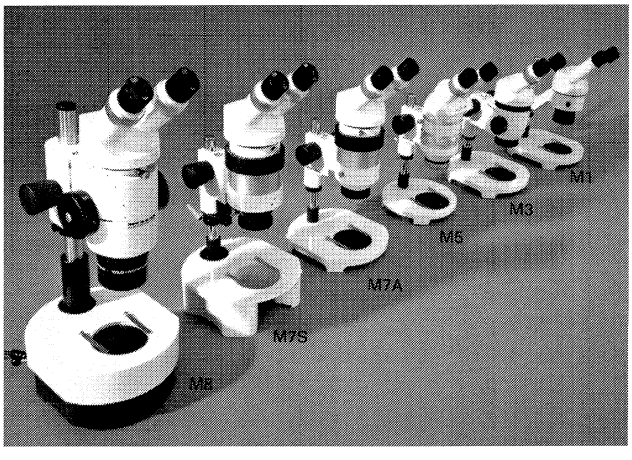

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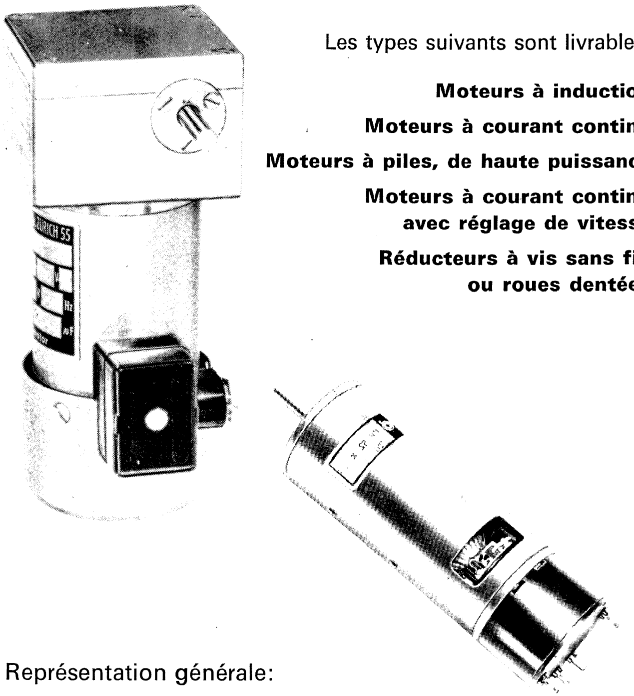

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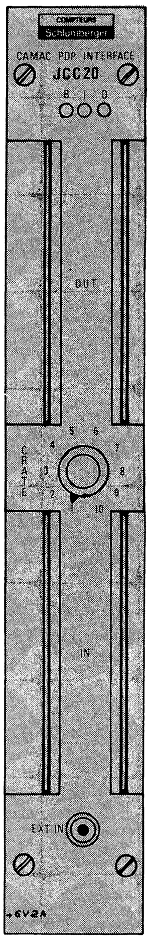

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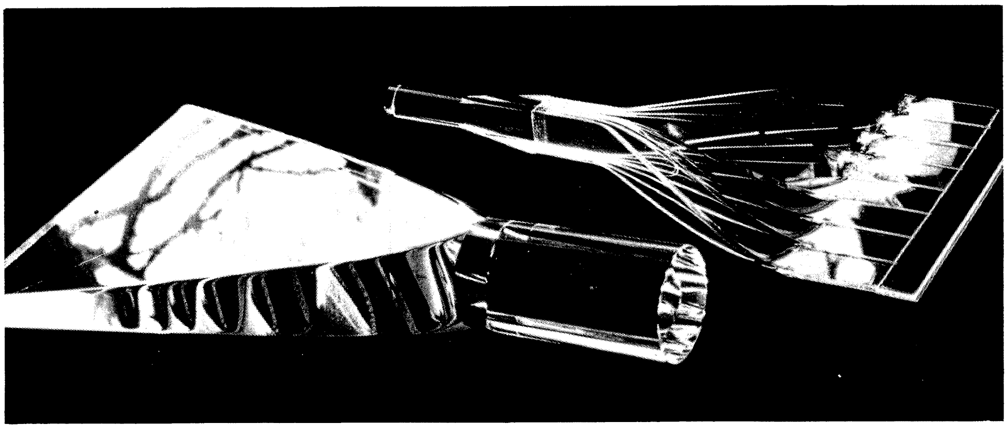

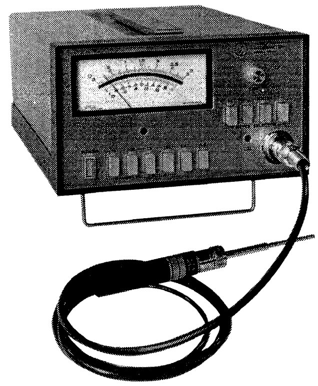


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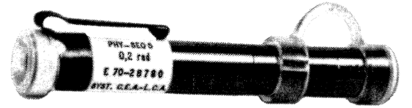

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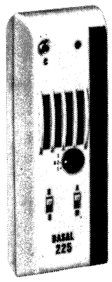

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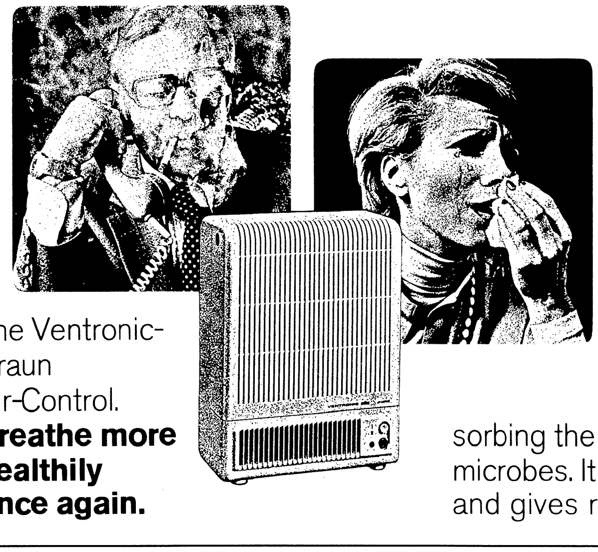

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The System

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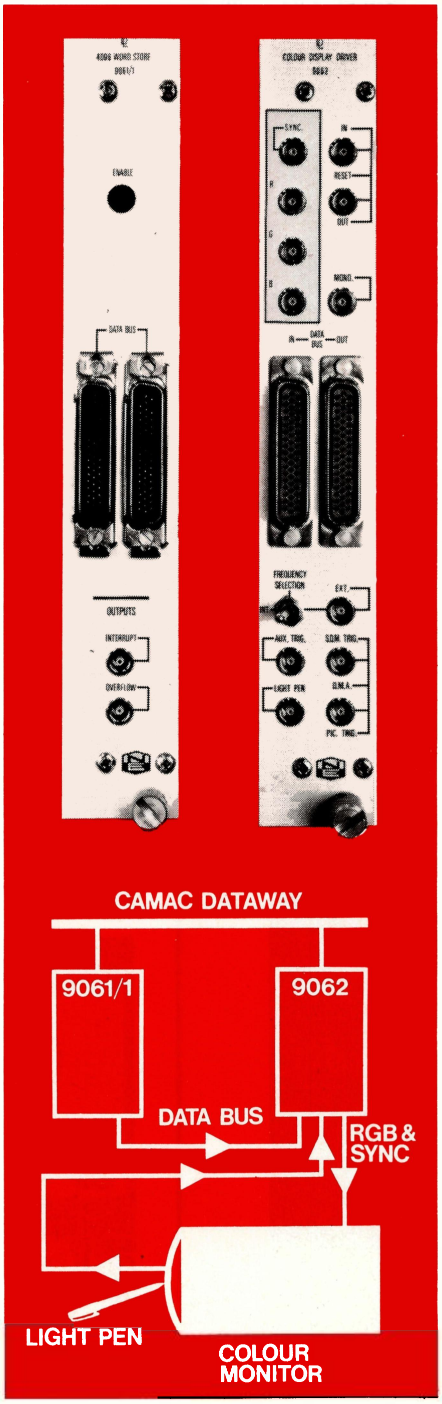

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- Stores 455 software designed symbols
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- Fast transfer via Data Bus
- Light pen or joystick inputs
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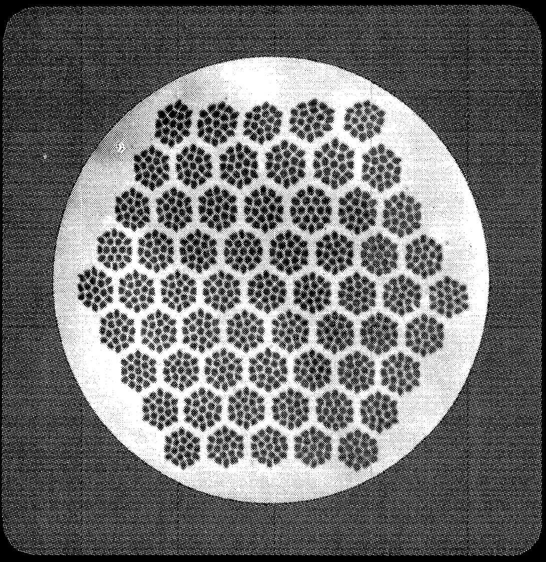

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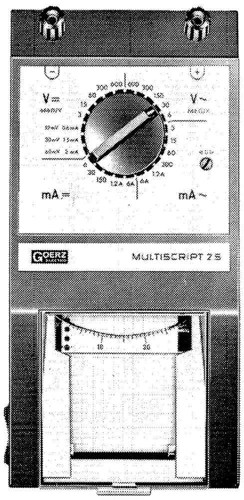

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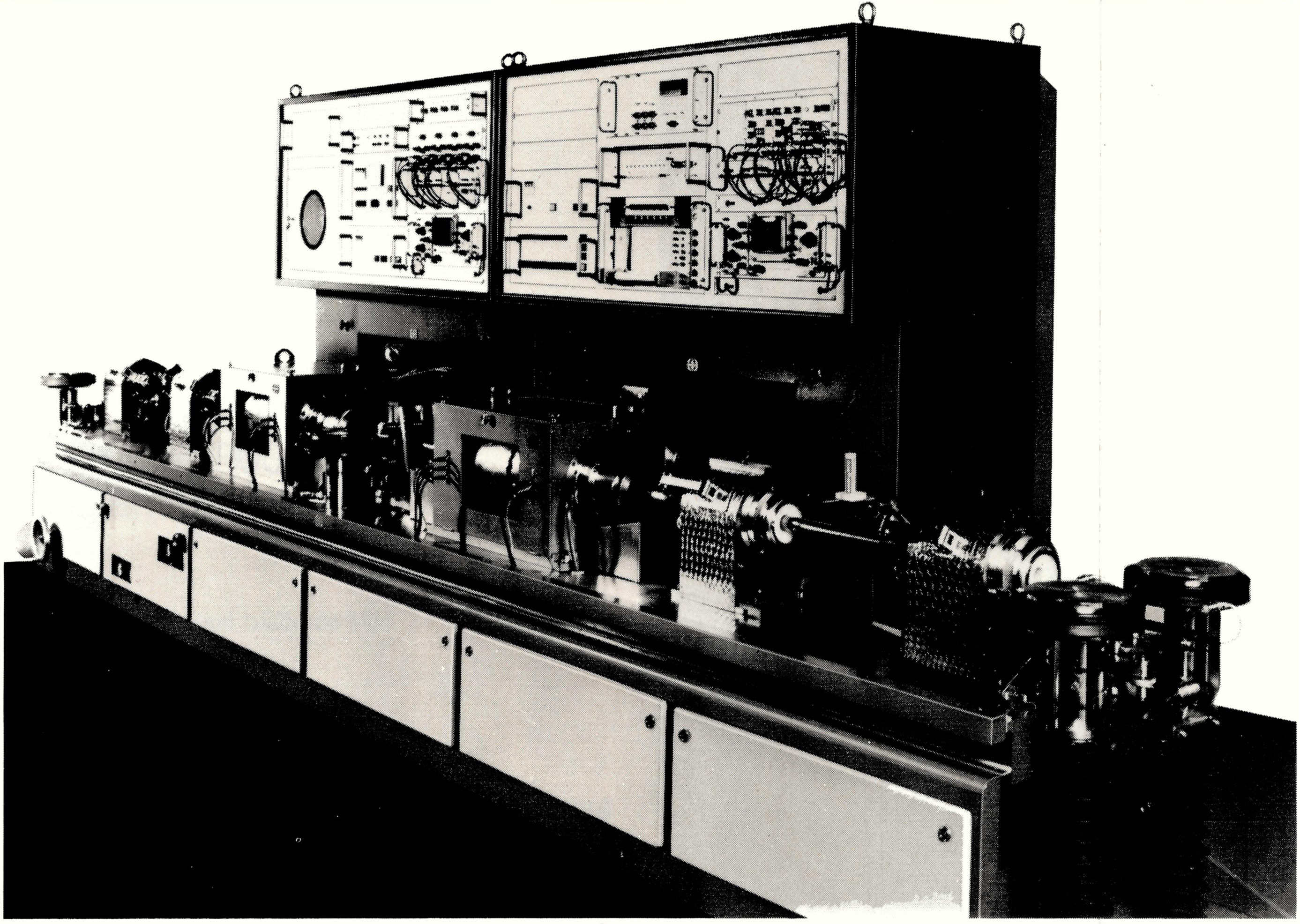

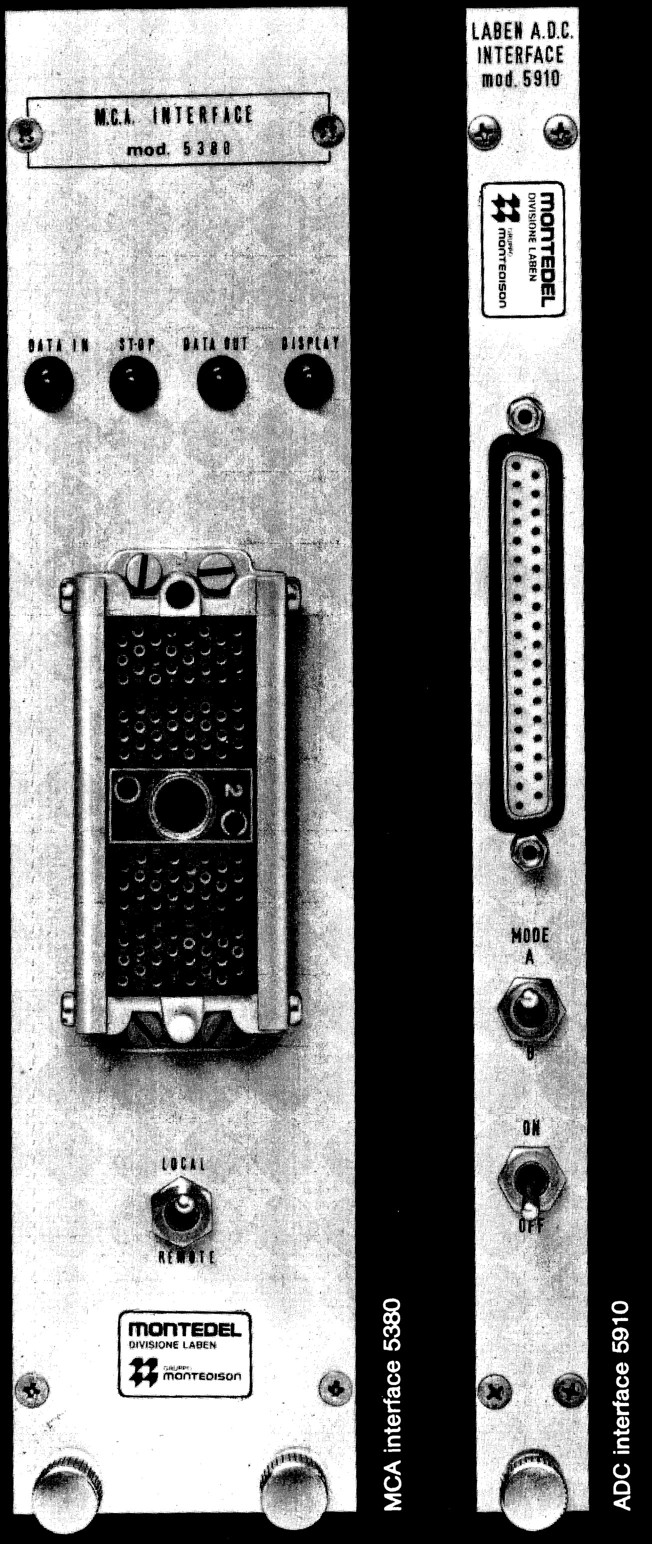
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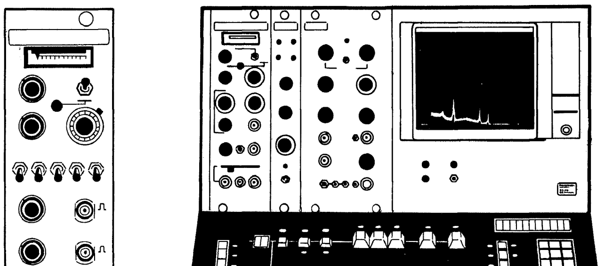

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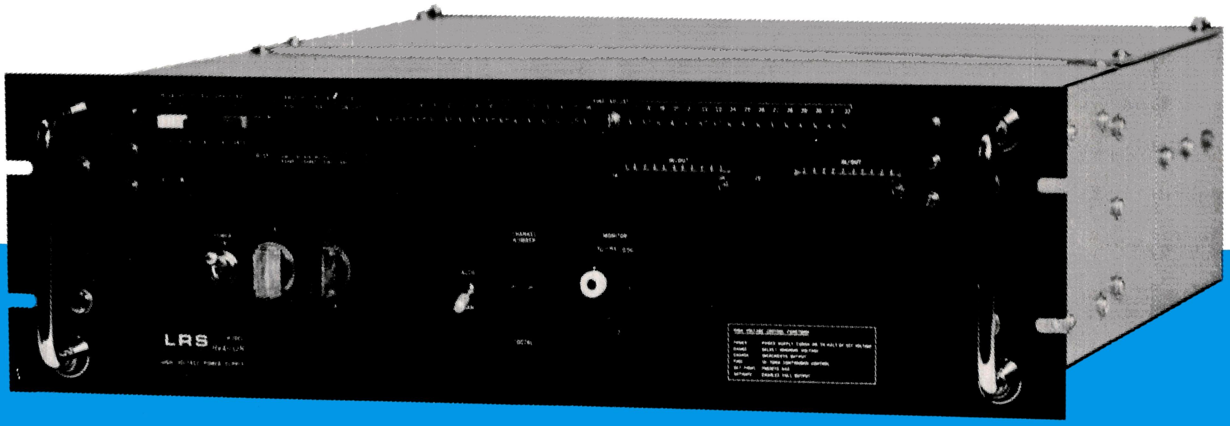

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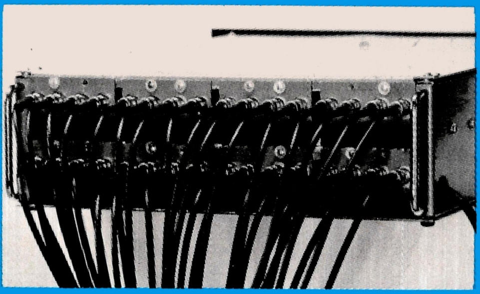

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