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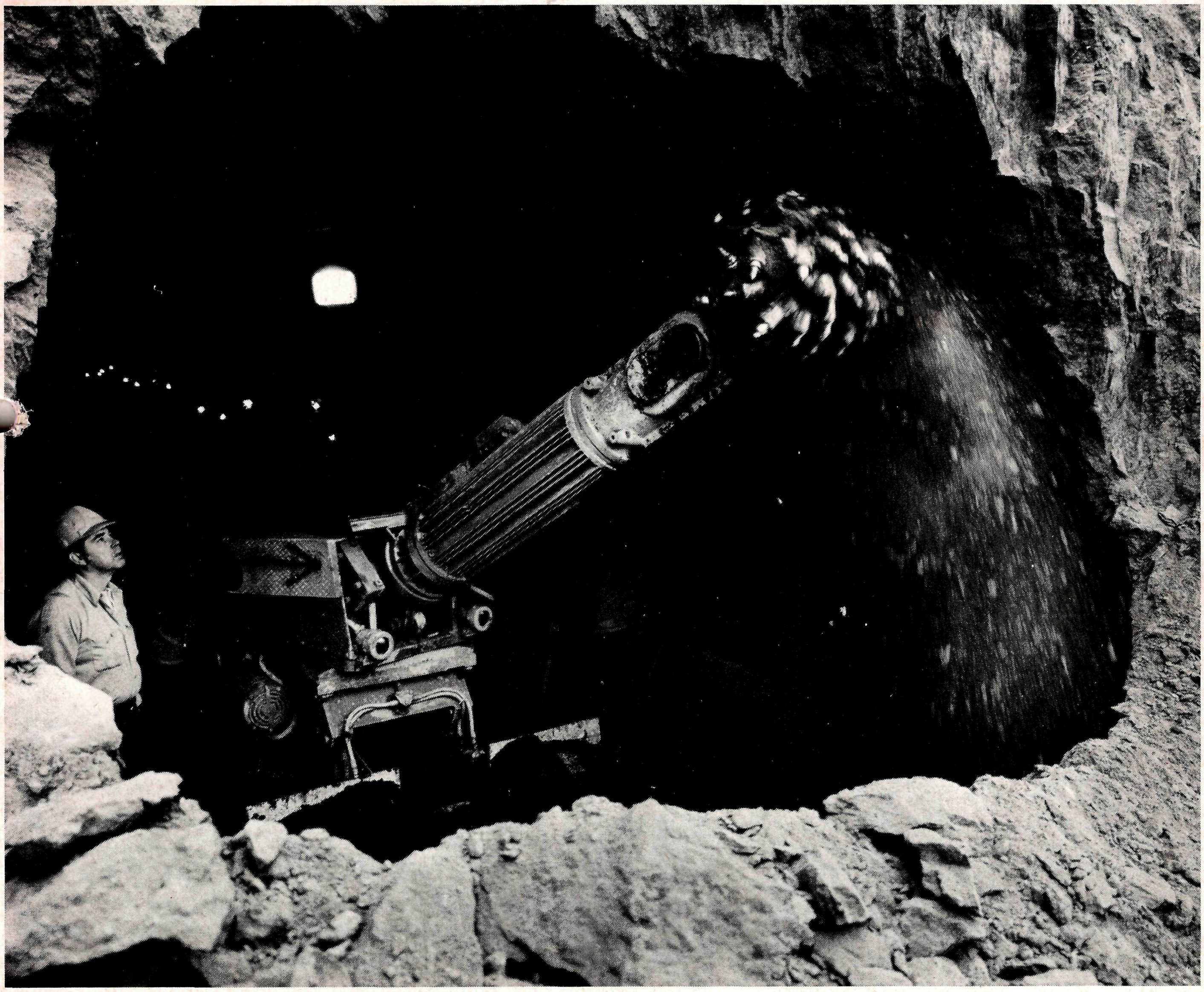

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Cover photograph: 'Break-through' at SLAC in the tunnel boring of the Berkeley/Stanford electron-positron storage ring, PEP. The photograph shows the tunnel opening, which was gratifyingly in the right place, being enlarged. This completes the first 800 foot stretch to be bored for the ring. (Photo Joe Faust)

Surprise at Gargamelle

One of the events recorded (via three cameras) in the heavy liquid bubble chamber, Gargamelle, using high energy neutrino beams from the 400 GeV proton synchrotron, where a neutrino entering from the left has interacted with an electron producing the spray on the right initially from a single electron track. Neutral current interactions of this type have been seen in numbers much higher than anticipated which is causing considerable confusion in the standard theory of what is happening.

One of the immediate objectives of particle physics research is to understand weak interactions and, in particular, the phenomenon of the weak neutral current which was discovered in the Gargamelle heavy liquid bubble chamber at CERN in 1973. This discovery was a major success for the gauge theory which attempts to unify weak and electromagnetic interactions, since it had predicted the existence of the weak neutral current.

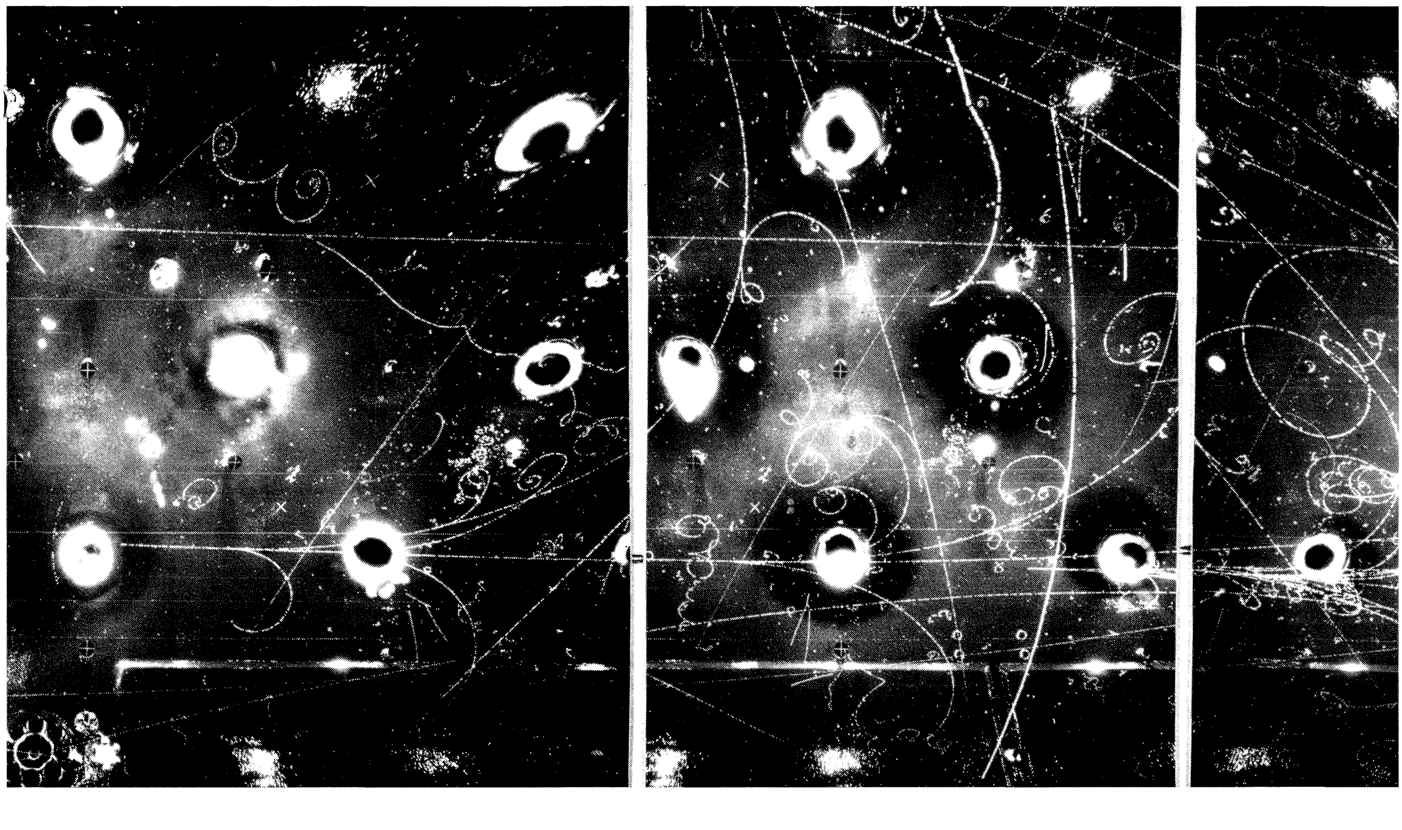
Experiments during the past few years have generally been in line with the standard gauge theory of weak and electromagnetic interactions. It began to look as though the dust was settling and that the neutral current could take its place in physics textbooks as an understood phenomenon.

However, the experiments up to now have concentrated on the neutral current interactions of neutrinos with nuclei, which are much more abundant than the corresponding interactions of neutrinos with electrons. A new investigation, using Gargamelle resited at the 400 GeV proton synchrotron, of the high energy elastic interactions of neutrinos and electrons using the wide band neutrino beam, has come up with totally unexpected results. The experiment, involving a Bari/CERN/Ecole Polytechnique/Milan/Orsay collaboration, is a rerun at higher energy of the classic 1973 study which saw neutral current interactions between neutrinos and electrons for the first time.

While the object of the exercise in 1973 was simply to search for this new type of interaction, the aim at the SPS is to measure the production rate of elastic electron-neutrino scattering at higher energies and to find if the neutral current phenomenon with electrons changes significantly with increasing energy. This would be new information on the leptonic neutral current which is much less known than the hadronic neutral current (the reactions of neutrinos with nuclei).

With Gargamelle filled with a mixture of 90 per cent propane and 10 per cent freon, 128000 pictures were taken in October and November last year. After careful selection, ten clear candidate electron-neutrino events were found and painstaking analysis revealed that a signal equivalent to just a small fraction of an event could be attributed to background processes which mimic true neutral current effects. So the ten events look good and provide the first measurements of this important process at high energies.

In the gauge theory of weak and electromagnetic interactions, which had so far appeared to be highly successful in accounting for the observed behaviour in neutrino experiments, one vital parameter is the so-called 'Weinberg-Salam' mixing angle. This pins down how the two neutral bosons — the photon of electromagnetism and the neutral intermediate vector



boson responsible for weak neutral current effects — appear in the theory and dictates how the usual electromagnetic phenomena are embedded in a unified picture of weak and electromagnetic interactions. Any measurement of neutral current effects gives a value for this mixing angle.

With most other experiments over a wide energy range consistently homing in on a value for a mixing angle near $\sin^2 \theta = 0.25$, a radically different result from the new Gargamelle experiment comes as a great surprise. The measurements on the production rate for electron-neutrino neutral current events at SPS energies gives the $\sin^2 \theta$ parameter as at least 0.74, vastly different from the value of 0.25 found for nucleon-neutrino neutral current interactions at any energy studied so far. The significance of this measurement is highlighted when it is pointed out that the conventional 0.25 value would result in less than two electron-neutrino events being seen in the 128000 picture sample. The chances of seeing ten events in such a big statistical sample when less than two are expected are extremely remote.

The differences in behaviour between electron-neutrino and nucleon-neutrino neutral current events could be attributed to a current which couples to electrons but not to nucleons. The change in behaviour of electron-neutrino interactions with increasing energy is, however, less easy to account for. Just as we thought we were beginning to understand what goes on, the theory of weak interactions has been thrown back in the melting pot and we can only speculate on what will emerge.

Could accelerators replace fast breeder reactors?

Questioning the 'usefulness' of high energy physics research has damped down considerably in recent years. One reason for this is the renewed vigour and liveliness of the research itself where discoveries and fresh insights are tumbling over one another. Another probable reason, leaving aside the more idealistic arguments about increasing human knowledge etc., is that the technology required for high energy physics research is finding extensive applications in other fields.

The degree of sophistication which accelerator and detector technologies have achieved has opened up uses, for example, in medicine, as intense neutron sources, in a host of synchrotron radiation applications, and, recently, in the prospect of a new route to thermonuclear fusion (see November 1977 issue, page 364). This last idea, that heavy ion accelerators could be the instruments to implode deuterium-tritium pellets, is a potential application of high energy physics technology which could prove of inestimable value.

Another topic, which has been simmering for some time, suddenly seems to be emerging strongly and is of the same stature as the heavy ion fusion concept. It is the idea of using accelerated proton beams to breed fissionable material. Perhaps the present unease about fast breeder reactors has prompted the increased interest in finding an alternative way to sustain the fuel supply for 'conventional' fission reactors.

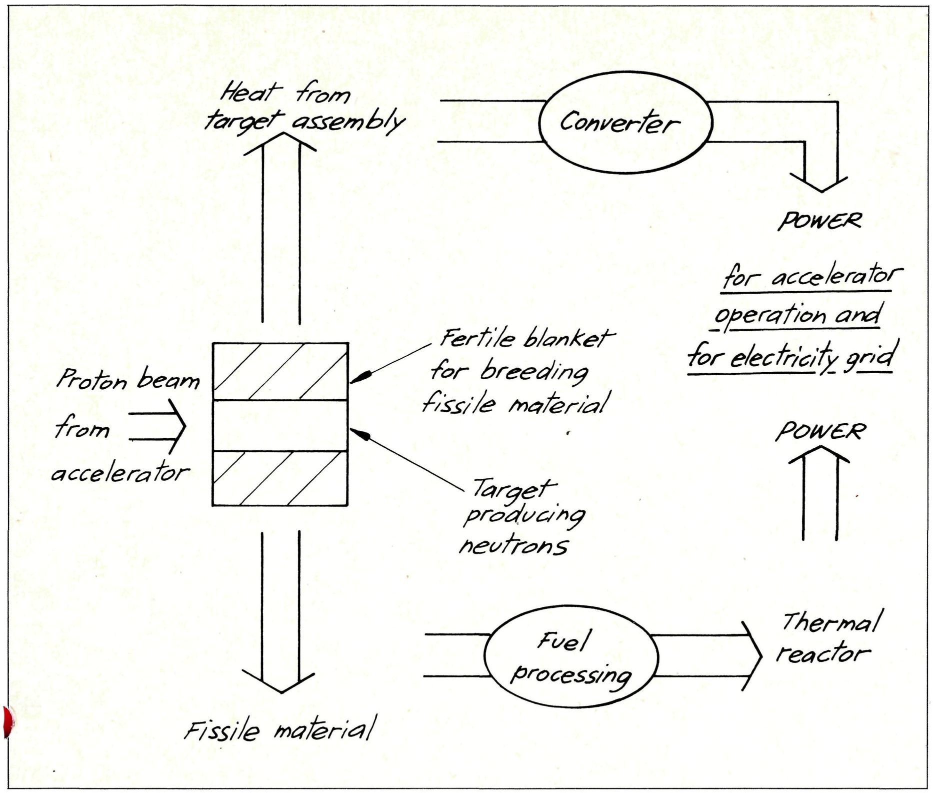
If nuclear fission is to continue as an energy source for long into the future, some method of manufacturing the fissile fuel from non-fissile material at a faster rate than the fuel is spent — the process known as breeding — has to be applied. This is because the conventional thermal reactor burns uranium-235 (which produces energy when its nucleus breaks up on absorbing an additional neutron) and the energy potential from the total known natural reserves of uranium-235 is only a fifth of that of the known oil reserves. Not many decades can go by before all the fissile uranium ore of high grade is used up and costs would then rise steeply.

The breeder technique which has received most attention so far, is that of the fast breeder reactor where uranium-238 nuclei receive fast neutrons from the fission of plutonium-239 and convert to plutonium-239. Burning plutonium-239 in the reactor core releases fast neutrons which breed more fuel in a surrounding uranium-238 blanket. This would ensure energy resources for a very long time since uranium-238 is 140 times more abundant in Nature than uranium-235.

There are, however, several worries about this technique mainly because of the high energy density in the breeder reactor core, which is not easy to control, and because of the dangers inherent in producing large quantities of plutonium-239.

Another approach to breeding fissile fuel starts from thorium-232 nuclei which receive slow neutrons and convert to fissionable uranium-233. The process is not as efficient as uranium-plutonium but thorium-232 is comparatively plentiful in Nature and conventional thermal reactor technology (rather than fast breeder technology) can be used since only slow neutrons are needed. Reactors fuelled with uranium-233 surrounded by a thorium blanket thus have attractions compared to the fast breeders.

However the breeding process for thorium is, by itself, not quite efficient enough. The uranium-233 fission has to liberate one slow neutron to sustain the fission chain reaction in the reactor core by seeding another uranium-233 nucleus. Then there are inevitable neutron losses from the reactor, usually listed as 0.2 to 0.3 neutrons per fission, and, on top of this, another slow neutron has to be available for con-



Scenario for the use of accelerators in a breeder system to convert thorium into uranium-233 which could be fissioned in conventional thermal reactors to produce power.

verting a thorium nucleus to replace the fissioned uranium nucleus.

If the system is to breed — creating more uranium nuclei than are initially burned in the reactor, the average fission has to yield over 2.3 slow neutrons. The uranium-233 to thorium-232 cycle falls short of this in practical systems, such as the CANDU (Canadian Deuterium Uranium) heavy water reactors, by some 10%.

If the uranium-thorium cycle is to be used as a breeder system, we need an economic source of neutrons to top up the few percent that the cycle itself does not provide in order to use up all the thorium. This is where accelerators could come in. It is worth underlining that the job of the accelerator is not to undertake the full breeding process but to top up what is achieved at the reactor itself.

The idea of accelerated beams producing fissile material is not new. Glenn Seaborg and his colleagues produced tiny quantities of plutonium-239 from uranium-238 using deuterium beams as long ago as 1940. The idea of using accelerators as a source of neutrons, which would then initiate fission, is more difficult to trace. The earliest relevant papers we know of date back to 1947 when Vanna Cocconi realized, while studying cosmic rays with boron trifluoride counters, that high energy particles ploughing into nuclear matter were sources of many neutrons. This was documented in several papers, some with Giuseppe Cocconi. In 1948, R.H. Goeckerman and I. Perlman saw 190 MeV deuteron interactions in bismuth giving twelve neutrons and, in the same year, P.R. O' Connor and Glenn Seaborg saw the same effect with alphas on uranium.

The first practical attempt to build an accelerator to perform this function was abandoned in 1952 when high grade uranium ore was discovered. This accelerator was the incredible MTA linac at Livermore, promoted by E.O. Lawrence, which was intended to use 500 MeV deuteron beams fired into beryllium (to produce neutrons) surrounded by uranium-238 which would convert to plutonium-239. When MTA died, the banner was taken up by W.B Lewis in Canada.

A Canadian team at Chalk River proposed a 1 GeV, 65 mA proton linac - the Intense Neutron Generator, ING - where spallation neutrons would emerge from a heavy metal target. The soundness of the proposal was checked on the Brookhaven Cosmotron where proton beams of up to 2 GeV were fired into metal targets and were found to yield between 20 and 50 neutrons per incident proton. By now, neutron sources using the spallation process are major projects at Rutherford and Argonne.

The ING proposal did not receive financial support but Chalk River has remained a strong proponent of such a scheme as evidenced at accelerator conferences in papers by P.R. Tunnicliffe (who has recently retired), J.S. Fraser and S.O. Schriber. Their present thinking centres on a 1 GeV, 100 to 300 mA proton linac. Each 1 GeV proton fired into uranium block would give 50 neutrons into a surrounding thorium blanket. This could top up a dozen uranium-thorium breeder reactors of the 1000 MW CANDU type in Canada.

Meanwhile proton linacs of high intensity have begun to look more realistic, thanks particularly to the work of Louis Rosen and his team on the 800 MeV LAMPF accelerator at Los Alamos. Los Alamos recently initiated a new study on fertile to fissile nuclear fuel conversion, using accelerators as the neutron source, in the Energy Division and the Accelerator Technology Division led by Ed Knapp. Oak Ridge are also interested and have completed a similar study in a team led by Fred Mynatt (Report ORNL/TM-5750). A lot of thinking about the possibility of breeding using accelerators was pulled together at an ERDA Information Meeting held in Brookhaven in January 1977.

At Fermilab, Bob Wilson has thought about the use of higher energy (1000 GeV) protons for the same neutron producing purpose (see December 1976 issue, page 440). The neutron yield goes up linearly and one 1000 GeV proton could produce about 50 thousand neutrons. A high energy comparatively low current accelerator could circumvent the high intensity problem of accelerators in the 1 GeV range. However, the neutron yield would be spread over a longer target needed to stop the high energy proton which could introduce different practical difficulties.

One surprising fact, in view of the potential importance of the topic, is that spallation neutron yields from targets of different elements and different configurations do not seem to have been studied in a systematic way.

These comparatively straightforward experiments would enable more precise figures to be fed into the very sensitive calculations used by the advocates of accelerators for fission systems. Some measurements are under way at the TRIUMF cyclotron in Vancouver and are planned at LAMPF.

Typical estimates are that a 1 GeV proton would produce 50 neutrons and 4 GeV of heat in a natural uranium target sufficiently large for the full spallation chain to occur. Some advocates propose that this production of heat could be put to good use, for example as the source of energy for the accelerator operation, but it may, in fact, only be a complication. The materials problems at the target would be severe and there is probably much to be learned from the fast breeder and fusion experts.

Since almost all the neutrons could convert a fertile atom to a fissile atom, a beam of 300 mA, 1 GeV protons could give a ton of fissile material per year. More importantly, this same beam, or a much less intense beam (say 25 mA) could be used to 'top up' the conversions already achieved in a thorium blanket around a uranium-233 thermal reactor. In this way fissile material could be bred, using the thorium-uranium-233 cycle, conventional reactor techniques and accelerator systems, without resort to the uranium-plutonium cycle or fast breeder technology.

Cost estimates can only be tentative until more precise figures can be associated with target performance and until accelerator technology has been extended to achieve the necessary machine parameters. In any case, the cost of producing energy from an accelerator-based system is unlikely to come out below the corresponding cost using fast breeders. But if the necessary development can be successfully accomplished, mankind may well judge the other advantages to be worth the cost.

ECFA Meeting

A plenary meeting of ECFA was held on 12 April at CERN under the Chairmanship of Marcel Vivargent, with the purpose expressed in its title — European Committee for Future Accelerators — very much in mind. The possible future projects which Europe may undertake were major items on the agenda.

ECFA has already given top priority to the construction of a much higher energy electron-positron colliding beam machine. This is now being studied at CERN in a 70 GeV version, LEP-70. This would be half the size of a 100 GeV version initially envisaged, for which some severe machine problems were found.

To involve the full European high energy physics community in the continuing discussion about the machine design and its physics programme, ECFA has set up a 'Working Group on LEP Studies' under the Chairmanship of Antonino Zichichi. It is likely to have four sub-groups looking at the machine characteristics, the theoretical considerations dictating the choice of the machine, the experimental programme and the detection systems. With the advent of this new Working Group, the ECFA Committee for Accelerator Studies, ECAS, has been disbanded.

A LEP Summer Study is to be held at Les Houches (France) and CERN from 11-22 September. The Study will be sponsored jointly by ECFA and CERN and will consist of a ten day meeting with limited participation at Les Houches, followed by an open two day summary meeting at CERN. A preliminary meeting to acquaint people with the present state of the LEP design was held at CERN on 3 May.

The Summer Study will involve about sixty people in the working sessions at Les Houches. Convenors will be J. Le Duff for 'machine parameters', Chris Llewellyn-Smith for 'electron-positron physics much beyond PETRA energies', M. Davier for 'experimentation at LEP', P. Strolin for 'design of interaction regions' and Klaus Winter for 'new ideas about detectors'.

At the April meeting, ECFA also looked at other accelerator possibilities which have high physics interest and which do not involve a major new project. At the end of presentations on the physics (by Chris Llewellyn-Smith) and technical considerations (by Franco Bonaudi), ECFA formulated the following statement:

1. ECFA restates that its highest priority is the rapid construction of a high energy positron-electron colliding beam system (LEP).
2. ECFA has examined a number of recent reports on the upgrading of existing facilities. Amongst these, apart from the proton-antiproton project which is already at a mature stage, ECFA considers the electron-proton collider proposals as having the greatest scientific merit.

Another Working Group was set up under the Chairmanship of John Mulvey — 'Working Group on High Energy Physics Activities in the CERN Community'. Its purpose is to draw up an inventory of existing resources and to monitor their evolution in the changing situation of European high energy physics. As a result of its work, ECFA should be in a position to comment on collaboration at international, national and University levels, on the development of national activities, on personnel requirements and on the distribution of financial resources.

Around the Laboratories

LOS ALAMOS
Factory managers' meeting

On 30-31 March, Directors and senior scientists from most of the world's 'meson' factories met at Los Alamos to discuss their common hopes and problems. Present were Louis Rosen (LAMPF), J.P. Blaser (SIN), Jack Sample (TRIUMF), Peter Demos and William Turchinetz (Bates Accelerator MIT), Claude Schuhl (ALICE, Saclay), A.H. Wapstra (IKO Amsterdam), René Buertey (Saturne, Saclay), Gunnar Tibell as observer (CERN) and Andrew Bacher (Indiana Univ.). The aims of the meeting were to improve communication of experimental results and programmes, to avoid unnecessary duplication, to coordinate computer work, and to discuss improvements to machines and detectors. It is intended to hold the meetings on an annual basis.

At the end of the meeting it was decided to pursue the following initiatives:

1. Timely dissemination of information of data obtained, experiments under way and planned, operational status of facilities, and plans for developing new opportunities.
2. Identify a liaison person at each facility to serve as a source of information and as a coordinator for special arrangements such as the exchange of personnel, organization of study groups, and of workshops and the cataloguing of available resources such as surplus equipment, computer programs, special reports on instrumentation and exchange of unpublished data from experiments of common interest.
3. Identification, by each Laboratory, of specialists who can be consulted with respect to specific technologies involved in experimental programmes, or accelerator improvements, of common interest.
4. Develop and distribute listings of current experiments to be updated every six months. A one-page yearly summary will be prepared for each experiment which has been in progress during that year.
5. Try to increase the opportunities for scientific and technical exchanges and collaborative experiments as a means of stimulating technology transfer and enhancing the effectiveness and productivity of all the facilities involved.
6. Encourage the attendance of observers from sister facilities at scientific programme committee meetings.
7. Develop a mechanism for the rapid dissemination of experimental results.

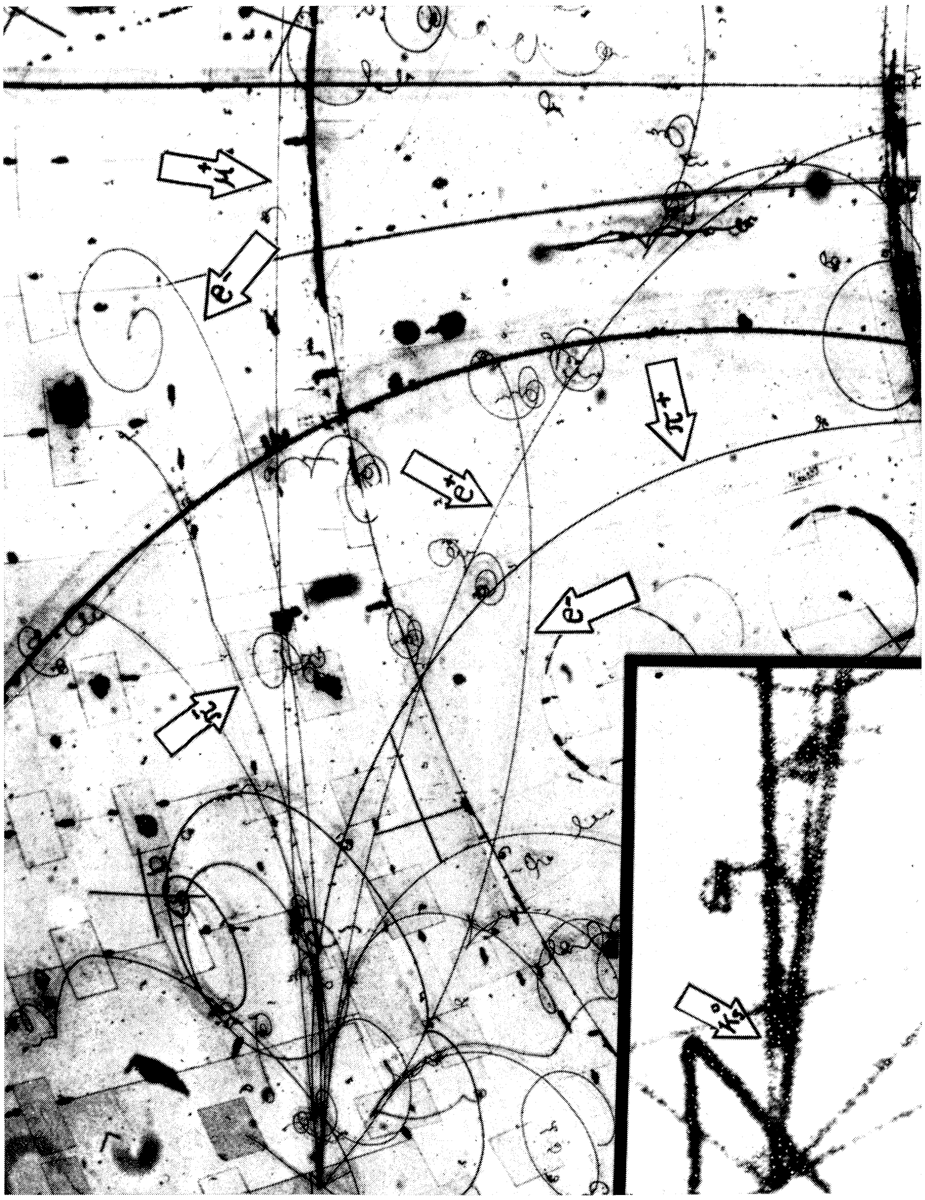
In order to accomplish the above objectives, the liaison persons will attempt to maintain good communications among the various Laboratories

Attendees at the Medium Energy Accelerator Management Conference, held at Los Alamos. Clockwise from head of table: Louis Rosen, Jack Sample, William Turchinetz (hidden from camera), Andrew Bacher, A.H. Wapstra, Gunnar Tibell, René Beurtey, Claude Schuhl and Peter Demos.

(Photo Los Alamos)

and with two secretaries - one for Europe and one for North America. For the next year the secretaries will be Claude Schuhl from Saclay and Jack Sample from TRIUMF. The secretaries will invite the management of other comparable facilities to participate in the activities and in future meetings.

FERMILAB
New four lepton event



A partial scan of photographs of neutrino-induced events in the 15 foot bubble chamber at Fermilab has revealed an unusual event. It has four leptons (two electrons, one positron, and a positively charged muon), a neutral kaon and seven gammas with a total visible energy of 32 GeV. It was recorded using the quadrupole triplet neutrino beam, the bubble chamber and a two-plane External Muon Identifier (EMI) by a collaboration of physicists from Wisconsin / Fermilab / Hawaii / LBL / Seattle. The chamber was filled with a 47% mixture of neon in hydrogen.

Several experiments have reported four muon events and trimuon events; this is the first reported four lepton event with three electrons. It appears to differ from the four muon event seen by the CERN / Dortmund / Heidelberg / Saclay collaboration (see December 1977 issue, page 406) in carrying a much smaller proportion of hadronic mass.

One electron has 0.91 GeV, the other 2.29 GeV, the positron 2.03 GeV and the muon 21.74 GeV. The neutral kaon decay occurs 1.7 cm from the vertex and has a good 3C fit with an energy of 2.06 GeV. The signatures for an electron come from bremsstrahlung gammas which are tangential to the track and subsequently convert into electron pairs. The schematic diagram shows dotted lines representing the gamma rays from the bremsstrahlungs. However, some conversions occur rapidly and appear as tridents along the electron track. Both the positron and low energy electron have a trident within 15 cm of the vertex. Background processes that could create these electrons are calculated to be small.

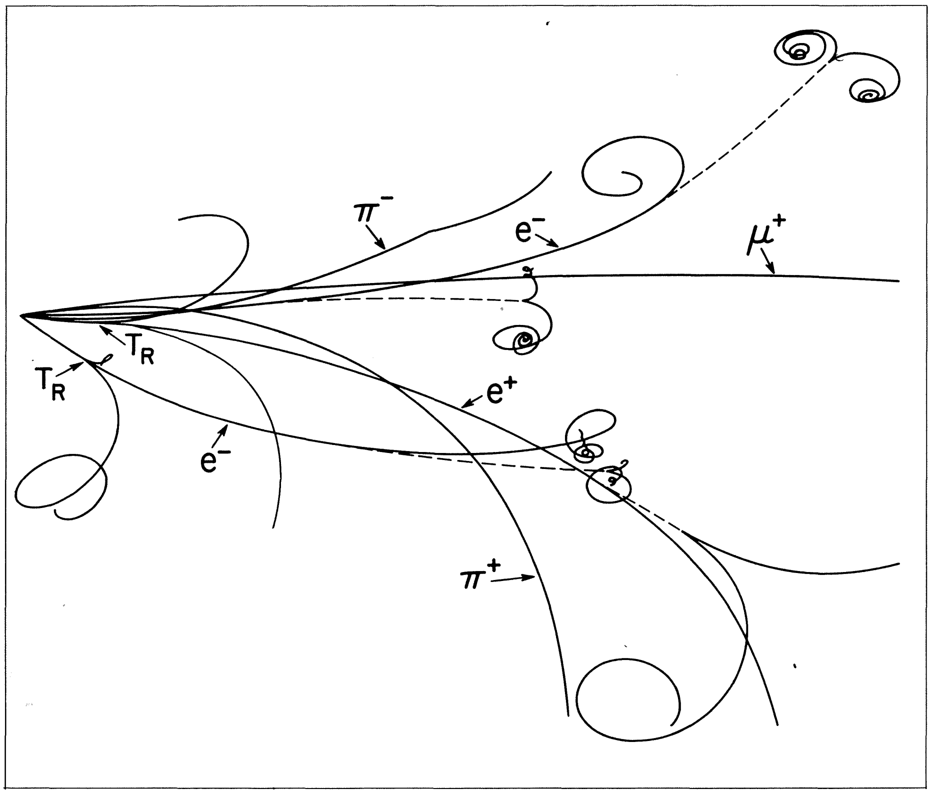
The muon track was extrapolated through nine absorption lengths and recorded in one chamber in each plane of the EMI. There were no other hits in either chamber. This event appears to have been produced by an antineutrino since the muon has the largest transverse momentum and more than half the visible energy of the event.

A prevailing view of neutrino interactions suggests that multi-lepton events are signatures for the production of new quarks or heavy leptons. Some theoreticians have suggested that this event could be typical of what would be expected from the production of a free top (or bottom) quark. However, it is difficult to reconcile the kinematics of this event with the currently popular theories. One possible interaction is production of charmed and vector mesons with the vector meson decaying into an electron-positron pair. The invariant mass of the pair is consistent with this decay but the expected rate per antineutrino event is much smaller than could normally have been observed in the exposure.

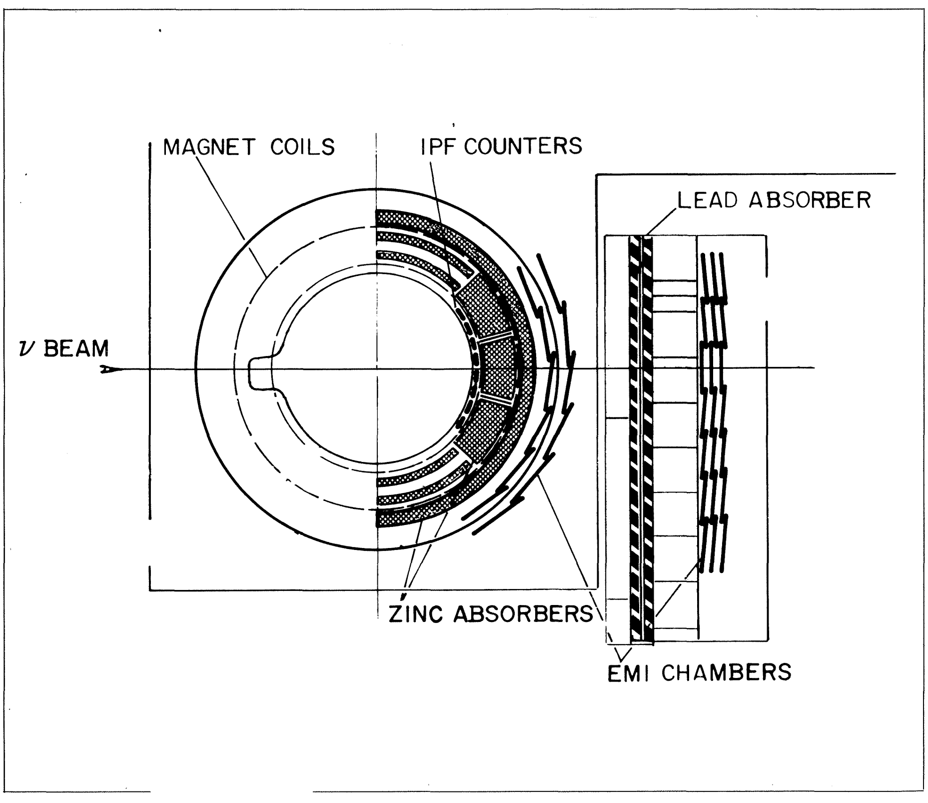
Internal Picket Fence test

For several years the External Muon Identifier (EMI) at the 15 foot bubble chamber has helped in identifying muons produced in neutrino interactions. Last year the EMI was substantially upgraded with more multiwire

The neutrino-induced four lepton event, including three electrons, seen in the 15 foot bubble chamber at Fermilab with an insert showing a magnified view of the neutral kaon decay into two pions. The event was seen in a Wisconsin/Fermilab/Hawaii/LBL/Seattle experiment using a neon-hydrogen mixture in the chamber. The area shown is roughly of 1 m side. The schematic diagram below (turned through 90°) indicates the electron identifications via trident production (T_R) and bremsstrahlung tangential to the track (indicated by dotted lines) converting to electron-positron pairs. The pion tracks come from the neutral kaon decay.



Plan view of the Fermilab 15 foot bubble chamber equipped with an Internal Picket Fence counter system (IPF). These wire planes are sandwiched inside the magnet coils near the operating volume. The External Muon Identifier (EMI) planes are located downstream of the chamber.



proportional chamber planes and new electronics. As a part of this improvement programme, a test version of an Internal Picket Fence (IPF) consisting of sixteen counters was built and installed. It is expected to increase the usefulness of the EMI especially for high-y, charged current and neutral current interactions as well as dimuon events.

Presently all the hits in the EMI (integrated over the entire beam spill) in the vicinity of the extrapolated bubble chamber track must be considered as potential muon candidates. However, most of them (85 to 90%) arise from neutrino interactions in the absorber and other material surrounding the bubble chamber. Because of multiple Coulomb scattering, the probability of an accidental match becomes very large for low momentum tracks.

The IPF counters were located inside the vacuum tank between the chamber and the superconducting magnet. They provide the times of all charged particle tracks emerging from the chamber. The time of the neutrino interaction is obtained by interrogating those IPF counters predicted to be hit by analysis of the bubble chamber picture. The event time obtained from the Internal Picket Fence can then be used to eliminate accidentals. It can also be used to identify a neutral current event if no hits occur in the EMI in a time slot specified by the IPF.

The environmental conditions place severe constraints on the Internal Picket Fence counters. They have to be vacuum-tight, small enough to go into the 4 cm gap between the chamber and magnet coil and operate near equipment at liquid hydrogen temperature, as well as in a magnetic field of 3 T. Each IPF counter has nine sense wires and eight field wires inside a 1.5 cm thick, 10 cm wide, 120 cm long rectangular aluminium tube. All sense wires are tied together to give one signal output per counter. The counter is contained in a vacuum-tight stainless steel vessel wrapped with many layers of super-insulation. Since argon-ethane was used for the gas, the temperature of the IPF is regularly monitored to keep it at room temperature with a small heater.

Last winter the test IPF operated for three months during a neutrino bubble chamber experiment and preliminary analyses have revealed promising performance. The detection efficiency of the counters was about 80% per track and the probability of a neutrino induced interaction hitting at least one counter was as high as 65%, even though the area covered by the test version is only 25% of the downstream region (roughly 2 m x 2.5 m) of the bubble chamber.

Encouraged by these results, Fermilab plans to install a larger scale IPF in the summer with much less dead space.

PEKING
Design of proton synchrotron

The Institute of High Energy Physics at Peking is developing the design of a 30 to 50 GeV proton synchrotron. It is felt that such a machine is within the present capacity of Chinese industry and one of the aims in the decision to build a particle accelerator, in addition to the desire to enter the field of high energy physics research as soon as possible, is to stimulate Chinese industry. The accelerator design has in mind the possibility of it being used in the injection system of a multihundred GeV machine, or a colliding beam machine, at a later date.

The preliminary design has a 200 MeV linac feeding a synchrotron about 460 m in diameter with peak magnetic field around 1.6 T. The anticipated intensity is about 5×10^{12} protons per pulse at a repetition rate of about one pulse every three seconds. The probable subsequent addition of a fast cycling booster could later take the intensity to over 10^{13}.

Contacts with industry are being made to produce the prototype of the first 10 MeV tank of the nine tank linac which will operate at about 200 MHz. The option of negative hydrogen ion injection to increase intensity is being kept open.

A site near Peking is being investigated and the aim is to have the accelerator constructed during the next five years.

KEK
Photon Factory

The construction of a 'Photon Factory' for synchrotron radiation research has been approved in the budget for Fiscal Year 1978 in Japan. Originally it was planned to be an independent institution but it was finally established as a part of the KEK Laboratory where the 12 GeV proton synchrotron is in operation. Construction will be completed in four years at a total cost of about $70 million of which $33 million is for the accelerator complex and experimental facilities and $37 million for buildings, including the electric power station and the water cooling plant.

The accelerator consists of a 2.5 GeV electron linac (total length 400 m) and an electron storage ring (diameter 50 m). The design performance is for an electron beam intensity of 50 mA from the linac at a repetition rate of 50 Hz. The storage ring has an electron beam intensity of 500 mA. The magnetic field is 1 T and the life of the electron beam is about ten hours.

The energy spectrum of the synchrotron radiation reaches a maximum intensity of 10^{16} photons per second per angstrom at the wavelength of about 2.3 Å without any specific devices. A superconducting 'wiggler' will be installed to raise the peak to 10^{17} photons at a smaller wavelength 0.38 Å.

Six channels will be provided for experiments. Outside KEK, there is a mighty Users' Association which has grown from the Users' Group at INS-SOR (the 300 MeV storage ring at the Institute for Nuclear Study, University of Tokyo) in the past fifteen years and now consists of 360 members.

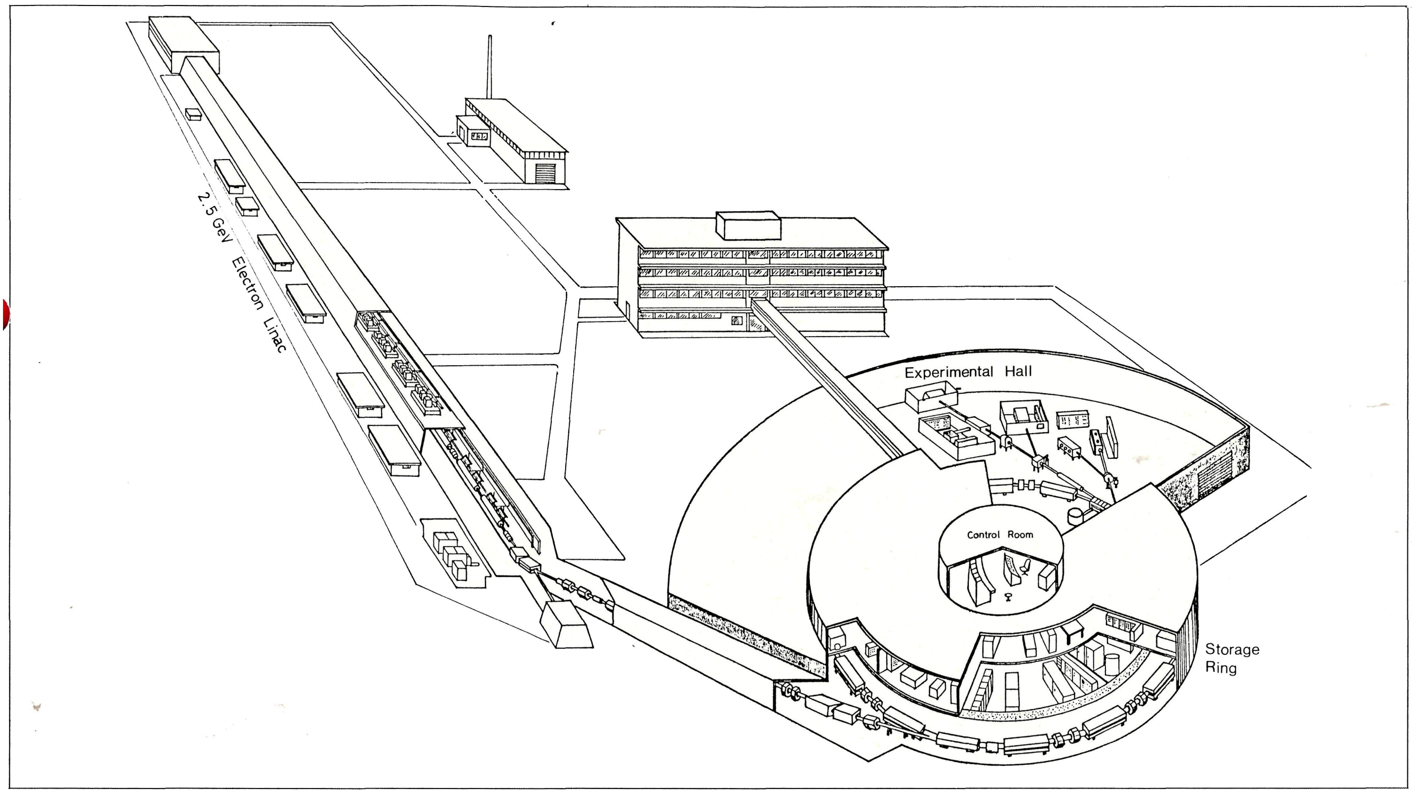
The project head is K. Kohra who has been in charge of the Users' Association and has been the most earnest promoter of the project. Head of the linac construction is J. Tanaka, who has been the head of the proton linac group of the KEK proton synchrotron, and the head of the storage ring construction is K. Huke, who has moved from being head of 1.3 GeV electron synchrotron group at the Institute for Nuclear Study in Tokyo. At present there are only a few people on the staff of this new project and staff from the PS are therefore collaborating with them in the machine construction. The total number of staff is expected to increase to about 160 in four years.

BROOKHAVEN
Light source takes shape

Both storage rings of the National Synchrotron Light Source, NSLS, which is to be built at Brookhaven are now at an advanced stage of design and all major parameters have been fixed. The NSLS, which has construction funds of $ 24 million, involves two electron storage rings to provide intense fluxes of synchrotron radiation for research in the X-ray and vacuum ultraviolet regions.

The present aim is to bring the VUV ring into operation in 1980 with eight-

The proposed arrangement for the 'Photon Factory' — an electron storage ring for research with synchrotron radiation — to be built at the KEK Laboratory in Japan.



een beam ports (including two fed by 'wiggler' sections to give smaller wavelength radiation). The X-ray ring will follow later having thirty beam parts (including five 'wigglers').

The project, led by Arie van Steenbergen, now involves about fifty people. Two committees have been set up to look at the research priorities of the user community and the costs that these will involve. An X-ray Committee is being chaired by T. Koetzle and VUV Committee by R. Holroyd. Martin Blume is the Users' Organization Coordinator and Morris Perlman Head of the Research Facilities Section.

SRFs in USSR

Since we already have two articles on synchrotron radiation research facilities this month (from Japan and Brookhaven) it is a good time to add some notes on facilities in the Soviet Union. We were helped by a report of Herman Winick from the Stanford Synchrotron Radiation Laboratory who toured the USSR last Autumn.

A Synchrotron Radiation Commission has been set up chaired by Vitaly Goldanskii of the Moscow Institute of Chemical Physics with Sergei Kapitza of the Moscow Institute for Physical Problems as Vice-Chairman and Evgeny Kosarev of IPP as Secretary. Research is under way at two synchrotrons of the P.N. Lebedev Institute (a 1.2 GeV machine, Pakhra, about 35 km from Moscow, and a 680 MeV machine, Fian, in Moscow), at the Erevan 4.5 GeV synchrotron, Arus, in Armenia and at the storage rings of Novosibirsk. There are also facilities at Tomsk (the 1.3 GeV electron synchrotron) and at Kharkov where there is a 2 GeV linac and a 100 MeV storage ring.

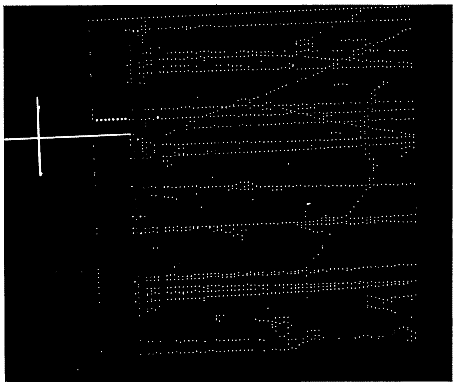
At Pakhra there is a single radiation beam line and a second is planned for a new experimental hall. Accelerated currents are around 10 mA and there are plans to increase this to over 1 A by using a 25-40 MeV racetrack microtron which is under construction as a new injector. They have put a lot of thought into the use of undulators to achieve radiation with special characteristics.

Fian was a scale model of the Dubna 10 GeV synchrophasotron. It now operates with currents up to 300 mA following the installation of a Tesla transformer, built at Novosibirsk, as injector. It has one beam line with five experimental stations.

At the Erevan Physics Institute (ERPI) the main research emphasis is in the field of high energy physics but the Director, I. Amatuni, is also very interested in synchrotron radiation research, which goes on in parallel plus about 100 hours of dedicated use a

The large ISIS detector constructed at Oxford University to be used for the identification of particles in the European Hybrid Spectrometer at the CERN SPS.

Direct display of signals from the wires reconstructing tracks passing through the detector ISIS which is undergoing tests on the Nimrod synchrotron at Rutherford. The tracks are produced by a beam passing 1.5 m from the signal wire plane. The detector, filled with an argon/20 % carbon dioxide mixture, was being run at 100 kV (140 kV has been reached). The drift time was 75 μs. Some low energy electrons were also observed.



year. The circulating current is 1.5 mA and there are two radiation beam lines. The machine has a 'wiggler' (built by Marzik Petrossian), which can produce fields of 1.8 T, and a beam line is being built to use the lower wavelength radiation which this will make possible.

ERPI also have plans for a storage ring (ERSINE) dedicated to synchrotron radiation research. The design group is led by Ivan Karabekov. The ring is for up to 2.5 GeV electrons, injected at full energy from Arus, with circulating currents up to 0.75 A in a ring 13 m in diameter.

The synchrotron radiation facilities at the storage rings of the Novosibirsk Institute of Nuclear Physics have been covered in the COURIER pages before (see, for example, March 1977 issue, page 62). Three VEPP rings are in action and a large and growing research programme with good instrumentation surrounds them. The programme is encouraged by the interest of the Director, A. Skrinsky. Adding to the existing equipment, a superconducting wiggler is scheduled for installation in VEPP-3 very soon.

OXFORD/FERMILAB ISIS/CRISIS

A new type of particle detector, known as ISIS — Identification of Secondaries by Ionization Sampling, was proposed at Oxford University in 1974 (see April issue, page 128). An ISIS has now been built and is undergoing tests on Nimrod at the Rutherford Laboratory. First results look good.

ISIS is a variant of the drift chamber technique which adds the ability of identifying very high energy particles by taking a large number of samples of the ionization they leave in their wake. For the different types of particle of a given momentum, the ionization is slightly different (e.g. about 15 % more for pions than kaons and 10 % more for kaons than protons over a wide range of energies from about 5 to 100 GeV). Many samples have to be taken to avoid being confused by Landau fluctuations.

The tested detector (constructed at Oxford and moved for tests to Nimrod) encloses a large volume 4 x 2 x 1.5 m³

CRISIS at Fermilab. Nothing to do with funding this time ... just a module of a detector known as 'Considerably Reduced ISIS' which is intended to be part of the hybrid system of the 30 inch bubble chamber. The main frame is shown with the central plane consisting of high voltage wires and the other two planes of sense wires.

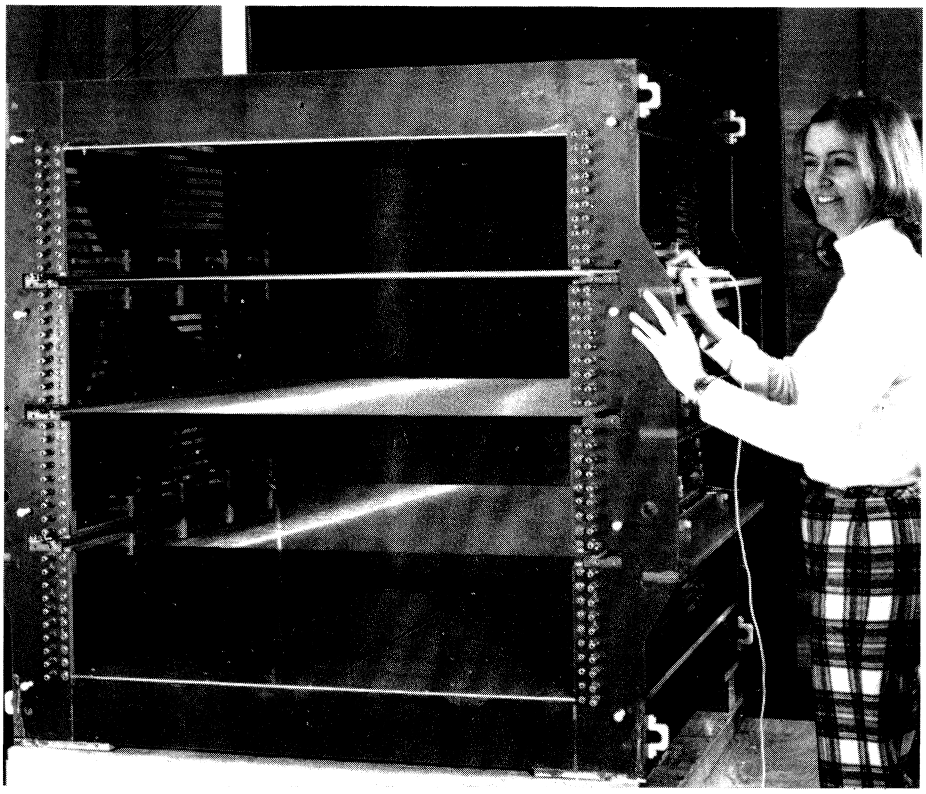
First results from tests of the CRISIS module showing the average ionization detected by the relativistic rise technique. The final detector will have three times the number of sampling cells to improve the resolution further.

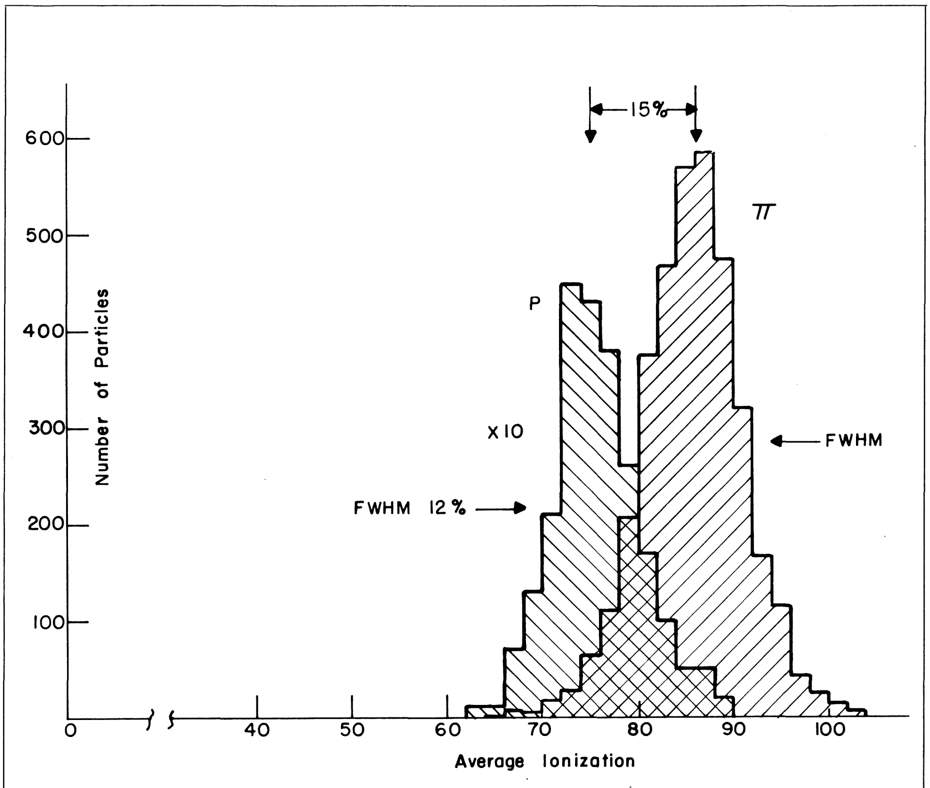
of gas in which a uniform electric field is established. A horizontal plane of signal wires runs along the centre and the volume is effectively divided into ionization sampling sections of width equal to the signal wire spacing. The time of arrival of signals gives particle positions accurately and the amplitude corresponds to the ionization caused in that sampling section and helps to identify the type of particle.

A larger volume ISIS is intended to act as particle identifier in the European Hybrid Spectrometer which is to be installed in the North experimental area at the CERN 400 GeV proton synchrotron, the SPS.

The multiparticle detection abilities have been confirmed as shown in the photograph. Everything is now ready to test the ionization abilities using pions and protons at 3.5 GeV/c tagged by a time of flight system.

The Oxford design has also been taken up at Fermilab for a hybrid system at the thirty inch bubble chamber. It has gathered the name CRISIS, — Considerably Reduced ISIS. The device, one meter on a side, delivered the design resolution during tests at Fermilab in November and December, 1977. The team, led by Vera Kistiakowsky, included contributions from MIT, Yale, Tennessee, Indiana and Fermilab.
The complete CRISIS will be 1 m x 1 m x 3 m and is destined for downstream particle identification in the Fermilab Hybrid Bubble Chamber Spectrometer which will also include a forward gamma detector and a 2 m x 2 m x 5 m segmented Cherenkov counter to be built by Michigan State with some assistance from Fermilab. The tested device was a full scale module which will be one-third of the final system. This module contains two sense wire planes and a central drift potential wire plane, as well as upper and lower drift potential planes. The sense wire planes consist of alternate





sense and cathode wires with a 4 mm wire separation. Pairs of wires are ganged together to form 64 channels providing signals which correspond to the amount of ionization produced in 1.6 cm of 80% argon, 20% carbon dioxide gas mixture.

The test was carried out with 40 GeV/c and 100 GeV/c pions and protons. At 40 GeV/c, the resolution for average ionization was 14% full width at half maximum, the expected value for the reduced system using 32 ionization samples for each particle which had the smallest values. The resolution is not sensitive to the exact percentage of samples used for the average in the range 30-70% (as has also been observed by the Oxford and CERN EPI groups).

The separation between the distributions for pions and protons is 15% as anticipated in 80% argon, 20% carbon dioxide at 40 GeV/c. Neither the pulse height nor the resolution depended on the drift distance, indicating the absence of field non-uniformities and electron attachment in the gas. The complete CRISIS will be identical in all respects but will have three times as many wires and therefore provide up to 192 ionization samples for each particle and 8% FWHM resolution. This will permit the separation of pions, kaons and protons in the momentum region from 4 to 40 GeV/c.

CERN Computer network

With the advent of the 400 GeV proton synchrotron, the demand for data communications at CERN has increased considerably. Particularly with the coming into operation of the North Experimental Area (see April issue, page 121), communication links have now to be set up over distances of several kilometres. At the same time, experiments themselves have become bigger and more sophisticated. By linking local computers at these experiments to the powerful resources available at the main computing centre, these experiments can have immediate access to the required level of data processing power.

The CERN Computer Network (CERNET), now coming into operation to serve experiments in the North Area, will provide flexible high speed data transmission to service ultimately the whole CERN site and to provide links to computer centres in other research centres or other computer networks. Connected to the Control Data and IBM computers at the main CERN computer centre, CERNET uses Modular Computing Services (Modcomp) computers as switching nodes of a 'store and forward' packet-switching type of communications network. This technique has been used before at CERN in the control system of the SPS.

In such a network, individual messages are not transmitted in their entirety but are broken up into small units or 'packets'. Each packet has a 'header' indicating the message to which it belongs, where it has come from and where it is to go. These individual packets are then forwarded separately through the 'mesh' network by the switching nodes, according to the transmission paths available at any time, and reassembled into the complete message when they reach their destination. This makes for efficient sharing of the available links and ensures uninterrupted service should individual links break down.

CERNET will provide a powerful and flexible communications network in the years to come, serving the growing data communications needs inside CERN and connecting with the fast developing data traffic outside.

In TIELINE, another computer communications development at CERN, the Control Data and IBM machines in the main computer centre have been linked so that users of the IBM 370/168 computer, which is soon to be joined by an IBM 3032 (see November 1977 issue, page 372), can transmit output and print files to the numerous on-line and remote job entry terminals attached directly to the Control Data computers. CERNET also provides a connection between the two types of computer and offers an alternative path for high speed file transfer.

A hundred years later

After a lapse of more than a hundred years, another item can be added to textbook atomic spectroscopy, following experiments at the CERN 600 MeV synchro-cyclotron (SC) where physicists at the ISOLDE on-line isotope separator have measured optical spectral lines from the rare element francium.

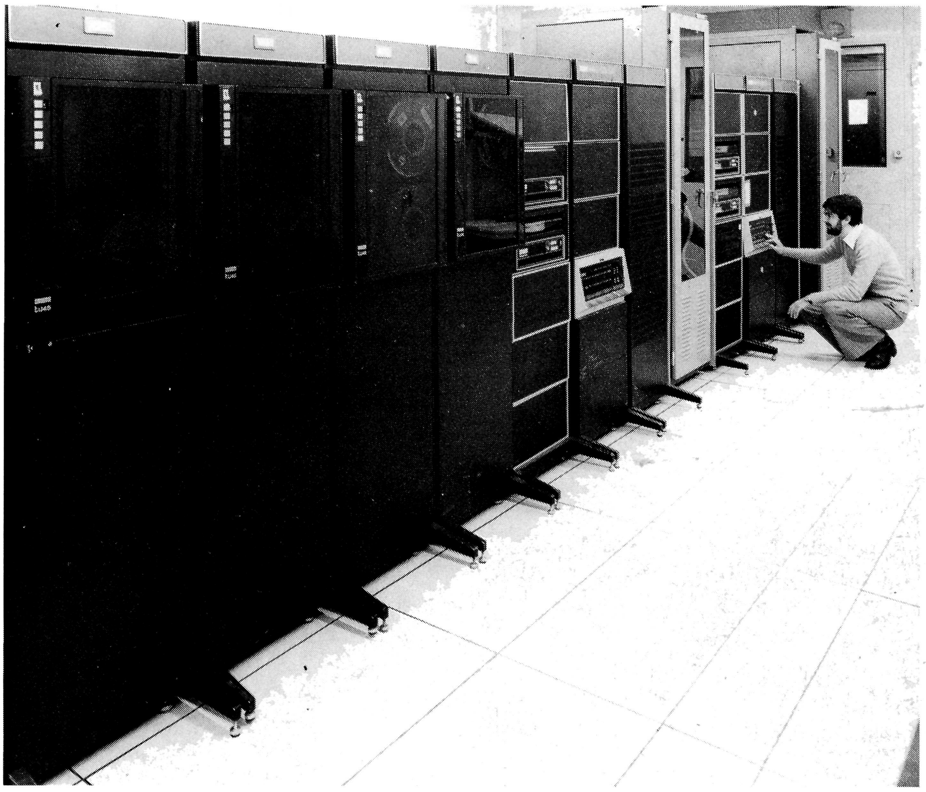
The most unstable of all the naturally-occurring elements, with even its most stable isotope having a half-life of 22 minutes, francium (atomic number 87) belongs in the same column of the periodic table of elements as the 'alkali metals' — lithium, sodium, potassium, caesium and rubidium.

The wavelengths of the main spectral lines of sodium were first measured by Fraunhofer in his investigations early in the 19th century of absorption spectra in sunlight, while the main spectral lines of the heavy alkali metals caesium and rubidium were discovered by Bunsen and Kirchoff in the 1860s.

Francium was discovered in 1939 by Marguerite Perey, working at the Curie Institute in Paris. It is produced in the alpha decay of actinium and so is

Part of the data acquisition complex for the European Muon Collaboration experiment soon to begin in the North Experimental Area at the CERN SPS. These computers are part of the OMNET communications network originally developed for the Omega spectrometer in the West Hall. This network is now linked to the main computer centre through the new CERNET packet switching network.

(Photo CERN 153.2.78)



naturally present in uranium minerals. It is estimated that, at any one time, there is less than an ounce of francium in the whole of the earth's crust. In the laboratory, the element is manufactured by bombarding heavy metals like uranium or thorium with protons.

At CERN, francium ions are provided by the ISOLDE separator, with two experiments using ion beams of different francium isotopes and applying different analysis techniques. Theoretical estimates gave the wavelength of the 7p-7s ground state transition somewhere in the range 7000 to 8000 angstrom units and one experimental group from Mainz started at the higher limit and worked downwards, while another group from Orsay began at the lower limit and worked upwards.

In the event, it was the Orsay group which won the race, as the spectral line was discovered near 7200 angstroms. In their experiment, specially prepared oxide surfaces supplied electrons to convert the ions into electrically-neutral francium atoms. These were then exposed to carefully controlled laser beams, reionized and analysed in a mass spectrometer. The detection rate remained constant until the laser was tuned to the wavelength of the spectral line and a clear shift was seen in the detected intensity.

Now that the position of the main transition has been found, the experimenters are looking for the fine structure splitting.

Nuclear traffic

Another story from ISOLDE concerns the growing collaboration in experimental nuclear physics between the separator and the reactors at the research complex at Grenoble in France. It well illustrates the way in which nuclear reactor and particle accelerator facilities can complement each other in studies using radioactive nuclides.

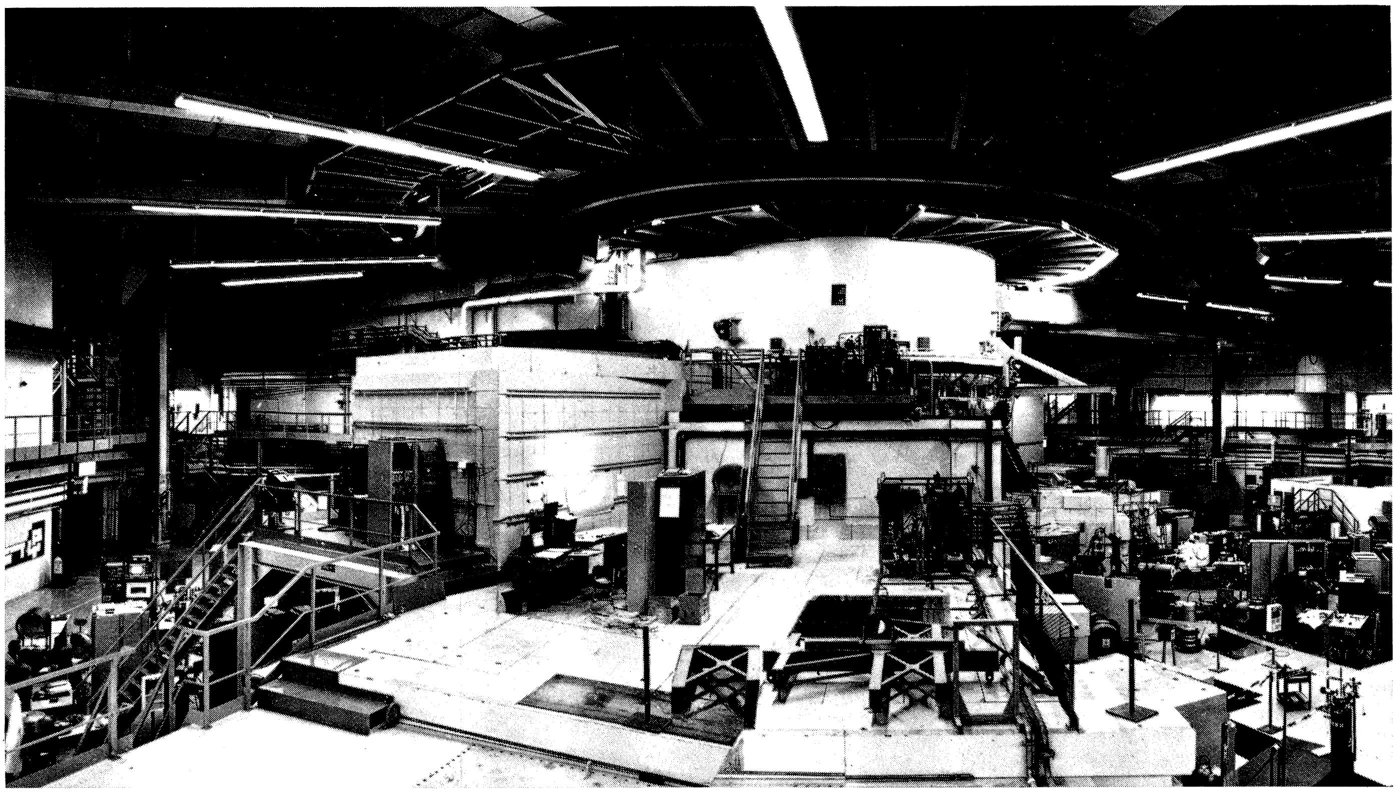
Two-way traffic in radioactive nuclides between CERN and Grenoble is now commonplace, with samples manufactured at one site being used in experiments at the other, so widening the fields of research at both centres. One study that has made great progress as a result of this cooperation is the investigation of atomic structure effects in X-rays, where radioactive samples were continually ferried at high speed between the experiment at CERN and the reactor at Grenoble.

Beta decay, through the capture by the nucleus of an inner orbital electron, leaves a 'hole' in the low-lying energy levels so that the daughter atom of atomic number Z retains, briefly, the outer electron configuration of the parent atom (Z + 1). This can affect the X-ray energies measured in high precision experiments and the shift in wavelength is expected to be largest for rare earth and actinide elements where the outer electron shells are filled before the inner ones. Rare earth isotopes can be prepared at ISOLDE and through reactor irradiation at Grenoble, so providing a twin supply of nuclide samples for study. This enables other small effects due to solid state structure to be identified.

The transport of samples between Geneva and Grenoble was an impressive exercise with health physics and transport personnel at CERN, French and Swiss customs officials, and health physics and reactor staff at Grenoble all involved in a finely timed programme. Samples for irradiation in the reactor were taken to Grenoble in a CERN car, where they were exchanged for newly irradiated ones. These highly unstable sources, with half-lives measured in hours rather than days, were then rushed back to CERN, where physicists were waiting to set them up in the experiment. The 150 kilometre trip between CERN and Grenoble, including packing, customs formalities

The experimental area at the high flux nuclear reactor of the Institut Laue-Langevin (ILL), Grenoble. Experiments have been carried out on neutron-induced charged particle emission from heavy nuclei, using radioactive samples prepared at the ISOLDE isotope separator at CERN.

(Photo ILL)



at the border and setting up in the experiment is usually accomplished in about four or five hours.

An experimental programme which has benefited from radioactive samples prepared at ISOLDE and taken to Grenoble is the investigation of the proton and alpha particle emission induced by thermal neutrons. Normally the binding energies in heavier nuclei suppress such reactions, and thermal neutrons only release charged particles from light nuclei. However, the reaction is favoured in highly neutron-deficient nuclei, such as those prepared at ISOLDE, and these unstable nuclear samples are studied in thermal neutron beams at the Institut Laue-Langevin (ILL), Grenoble.

The first nuclide to be prepared at ISOLDE and sent to ILL for study was rubidium-84. It provided the first example of thermal neutron-induced proton emission in a heavy nucleus. Experiments have now been carried out using argon-37, bromine-76, cadmium-109, xenon-125, xenon-127 and caesium-132.

This collaboration is still in its infancy but the increased range of radioactive samples and the wider selection of measuring and detection capabilities, should pay handsome dividends for the European nuclear physics community.

DESY* DORIS running at 9.4 GeV

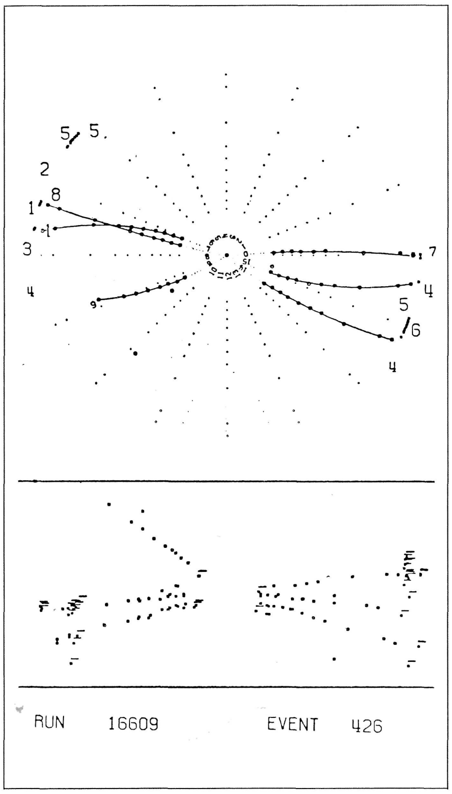
The electron-positron storage ring DORIS at DESY is running successfully at centre of mass energies of more than 9.4 GeV, the highest energy ever reached in electron-positron collisions. Peak luminosity is currently 1.5×10^{30} per cm^2 per s giving a mean of over 20 nb to both interaction regions during the last week of April.

Two groups operating the well-known detectors DASP and PLUTO are scanning to find the Upsilon resonance discovered at Fermilab by the Lederman group (see August 1977 issue, page 223). The first interesting observation was the two-jet character of most of the hadronic events at these energies seen by the PLUTO Group. The effect was also seen in DASP. These extremely interesting events are seen at all energies covered up to now by the scan. They were, in fact, expected from theory and from data at lower energy from SLAC.

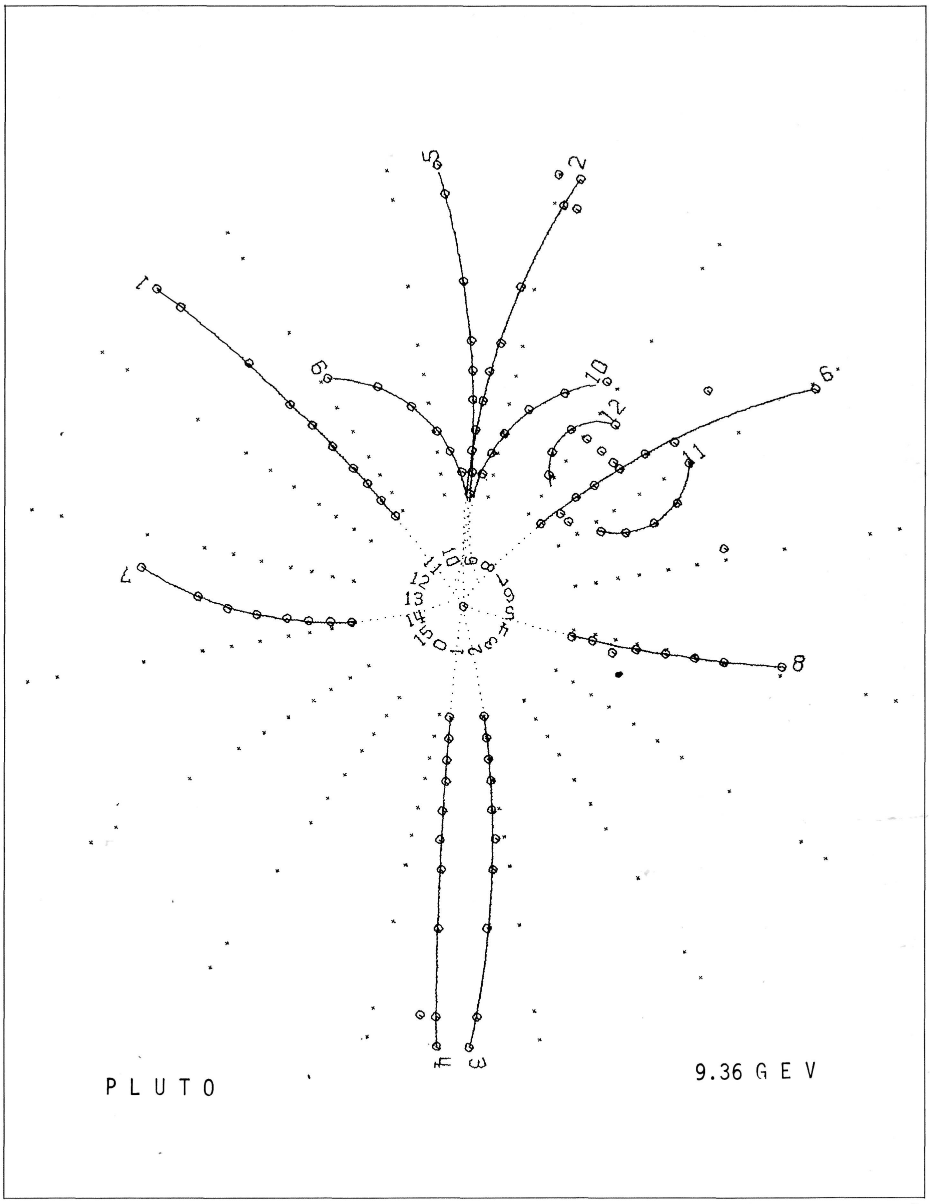
The total hadronic cross-section is of the order of 4 nb providing only 80 events per day to each one of the two groups at DORIS. Relevant results regarding the resonance are expected in the near future. The event shown in Figure 2 seems to contain the correct greek character ... perhaps a good sign.

* Later news from the beginning of May — a narrow resonance has been seen around a mass of 9.46 GeV. More details in the next issue.

1. Typical hadronic jet event obtained during one of the runs of the PLUTO detector on the DORIS electron-positron storage ring at 9.36 GeV centre of mass energy.
2. A particularly beautiful event from PLUTO with some resemblance to a particular greek character ...
3. A jet event as observed in the DASP detector.



1.



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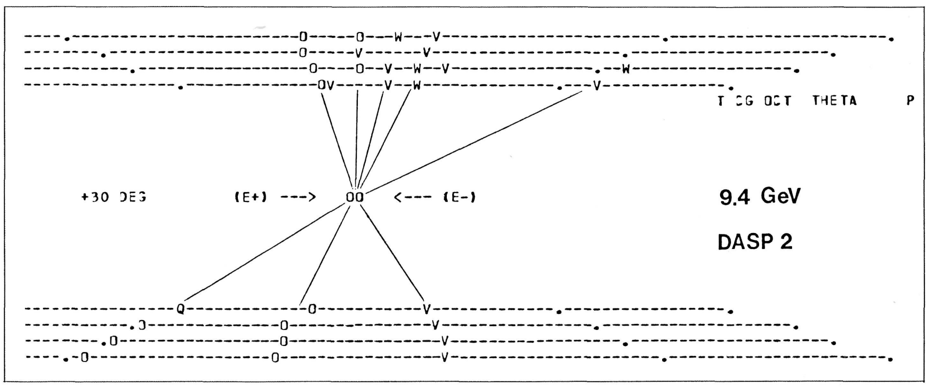


3.

Other experiments on DORIS were discussed at this year's 'DPG-Frühjahrstagung für Teilchenphysik'.

Results from the DASP detector and the DESY/Heidelberg experiment were reviewed, especially in the context of the expected eta states of charmonium. The new measurement of the radiative decay of J/psi into fγ at the PLUTO detector was of topical interest. The angular distribution in this reaction offered the first opportunity to check and verify detailed QED predictions.

The last link in the chain of arguments in favour of the charm model, the F meson, is supposed to carry both charm and strangeness. This long awaited particle was discovered last year by the DASP group at DESY. At the DPG meeting the group presented convincing new evidence both of the 4.4 and 4.15 resonances. The correlation of eta mesons and soft photons, which is characteristic of the production and decay of F mesons in conjunction with its excited partner F*, could be confirmed in the 4.4 region (see August issue 1977, page 235). In addition, a strong eta signal was seen in the 4.15 region without any soft photon correlation, indicating the production of $F\bar{F}$ at this resonance. All signals are correlated with direct electrons. This proves that the eta meson is indeed produced in a weak process as expected in charm decays. From its decay into an eta and a pion the mass of the F meson was determined as 2.03 ± 0.06 GeV/c^2.

The heavy lepton tau was established through 'anomalous' muon-electron and muon events at SLAC and DESY. Since then, efforts have been concentrated on the electron decay mode. Due to the low momentum cut-off, these measurements are sensitive even very near to the tau production threshold, where the lepton spectrum from tau decay is still relatively soft. DASP and DESY / Heidelberg groups have analysed their data looking for anomalous lepton signals down to 3.6 GeV centre of mass energies. In fact, DASP found anomalous electron events at the psi prime resonance (3.68 GeV) which they could unambiguously attribute to tau production (see January issue, page 18). From this measurement the mass could be determined very precisely as 1.807 ± 0.02 GeV/c^2. DESY / Heidelberg could do even better. They confirmed the signal at psi prime and got a small signal at 3.6 GeV. Combining their anomalous electron and muon data they determined a mass value of 1.792 GeV/c^2. Both, measurements shift the tau mass below the charm threshold, thus removing any doubt about possible confusion with charm.

Due to the axial component of the weak current, a decay into three pions is predicted. The PLUTO group looked into this decay channel and found a strong signal in the electron plus three pion final state. From the electron spectrum the tau origin of these events can be demonstrated. Further analysis of the mass distribution shows that the full signal can be attributed to a tau decay into rho-pi-neutrino with rho-pi in a s-wave state. This proves that an axial piece must be present in the weak decay current. The rho-pi mass distribution can best be described by a resonance in the 1^+ s-wave, which hints at the A_1 meson. The experimental branching ratio corresponds to the theoretical expectation.

The wonderful world of helium-3

Parity violation — the absence of a universal left-right symmetry — was first seen in weak interactions some 25 years ago. However, violations have only been detected in the more traditional weak interaction which shuffles around the electric charges of the participating particles (charged current interactions).

In 1973, experiments at CERN discovered that there is an additional component in weak interactions which is electrically neutral and leaves the charges of the participating particles unchanged. This 'neutral current' has important implications for the possible unification of electromagnetic and weak interaction phenomena and, since its discovery, physicists have looked for signs of left-right asymmetries in neutral current interactions, with little success (see December 1977 issue, page 422). Until this parity violation is pinned down, theoretical progress is difficult.

Recent work in a totally different area of physics has indicated that parity violating neutral current effects could show up somewhere else — in the behaviour of the remarkable liquid of the isotope helium-3.

Although helium-3 occurs naturally, the techniques to isolate it in sufficient quantities to do experiments were only perfected in the late 1950s. Like its more abundant partner helium-4, it becomes a superfluid at very low temperatures. The mechanisms responsible for this 'superbehaviour' are very different for the two isotopes.

The helium-4 atom has integer spin and is therefore a boson. There are no restrictions on the number of particles which can occupy the same energy level. At very low temperatures (a few degrees Kelvin) the helium-4 atoms tend to accumulate in the lowest energy state (Bose condensation) and this grouping together of atomic properties results in the superfluid behaviour which has been known and studied for over forty years.

The helium-3 atom on the other hand contains an odd number of spin one-half particles and is, therefore, a fermion. Fermions obey the Pauli exclusion principle which restricts each energy level to just one particle, so that no comparable condensation process occurs at low temperatures. For a long time, people believed that helium-3 would not show superfluid properties.

At about the same time as helium-3 was becoming available in sufficient quantities to do experiments, a quantum theory of solids was being developed which explained the phenomenon of superconductivity in metals. This theory (named the BCS model after John Bardeen, Leon Cooper and Robert Schrieffer) proposed that fermions of opposite spin would have a great affinity for each other at low temperatures, giving boson-like electron pairs which could wander at will through a metal and produce the superconducting effects.

This binding ('Cooper pairs') can also occur in any other low-temperature system of fermions — like helium-3. Although these pairs of helium-3 atoms are electrically neutral and so cannot produce superconductivity, they can still wander easily through the liquid helium sample and produce some form of superbehaviour. This superfluidity of liquid helium-3 was long suspected by theorists but was observed in 1972 only after the development of refrigeration techniques to attain millikelvin temperatures.

Encouraged by this success, theorists studying helium-3 went on to make more predictions. The Cooper pairs, they said, must also have a magnetic moment, but unlike the thermally disoriented diatomic pairs in an ordinary gas, these pairs all rotate in a preferred direction. This should

... meanwhile back in Canada ... In a letter to Physics Today (April issue), a reader points out the existence of a Black Hole which has been known for a long time. This one is a local beauty spot in Western Nova Scotia.

produce a definite ferromagnetic effect and, this year, experiments at the University of California at San Diego have provided the first evidence for this bizarre form of ferromagnetism.

One of the leading lights in the study of liquid helium, theoretician Tony Leggett, has gone a step further and predicted that liquid helium-3 should have an electric dipole moment as a result of the neutral weak interaction. The effect of this dipole moment should increase with the size of the sample to give a macroscopic effect which, in principle, should be detectable.

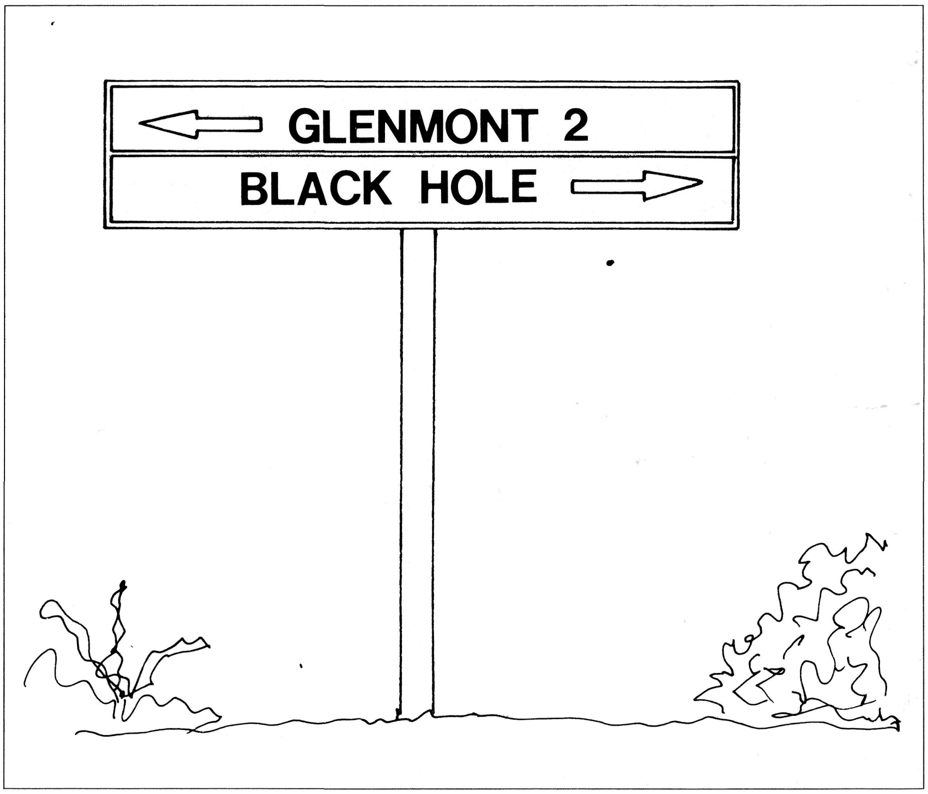
Time reversal invariance normally precludes an atomic system, characterized by a single angular momentum value, from having an electric dipole moment. Indeed tests on time reversal invariance to a higher degree of sensitivity are under way at the Institut Laue-Langevin in Grenoble, establishing an upper limit for any electric dipole moment of the neutron.

In an ordinary atom, the orbital spin angular momenta of the electrons and nucleons are not separately conserved but couple together to produce a total atomic angular momentum. However if the orbital and spin angular momenta are uncoupled, the restrictions of time reversal invariance are less strict and an electric dipole moment can exist.

In superfluid helium-3, the relative orientation of the spin and orbital effects are fixed so that the two components of angular momentum no longer precess around each other. This means that in principle a permanent electric dipole moment can be produced as a result of the weak neutral current interactions between nucleons and orbital electrons.

Estimates of this dipole strength indicate it to be very small, giving an energy 10^5 times less than the thermal excitation energy even at millidegree temperatures. However, the effect is proportional to the applied electric field and has a sharply defined preferred direction unlike the thermal excitations. This could make detection of this tiny electric moment possible.

As well as providing entirely new evidence for the weak neutral current, such an electric moment would be the first macroscopic signs of parity violating mechanisms at work in atomic forces.



Black holes large and small

Recent observations with optical telescopes in the USA have revealed that the giant distant galaxy, codenamed M87, could have a black hole at its centre. This is initial evidence for the existence of these bizarre concentrations of matter, predicted as far back as 1797.

Theoretical work in the past ten years has used the concept of black holes as a prolific source of new ideas, ranging from a possible mechanism for quasar production to new quantum effects (see October 1977 issue, page 334). This new black hole 'sighting' (black holes by definition cannot be seen) could provide fresh impetus for the theorists in their quest for fresh insights into the workings of Nature.

Black holes are giant stars which have long fizzled out and, without any supply of internal energy to give them shape, have been swallowed up by their own gravitational fields into immensely heavy centres of mass, so small and so heavy that the velocity needed to escape from their surface exceeds that of light. As a result, nothing can emerge from a black hole, while it voraciously devours anything coming within its 'event horizon'.

From the start, measurements on M87 revealed that unexpected things were going on. The galaxy was found to be tremendously energetic, pouring out an absurdly high amount of radiation, while radio astronomers discovered minute regions of intense activity deep inside the galaxy.

Following up these first investigations, photometric studies saw a brilliant speck of light, equivalent in brightness to 10^8 suns. Further optical work showed that the velocity of circulating matter in M87 increases dramatically near its centre. This is thought to be the last convulsions of the doomed galactical matter before it is finally sucked inside the event horizon of the central black hole and lost forever.

Besides these stellar black holes which have evolved over a long time, theoreticians have also suggested that tiny primordial black holes could have been produced where pressures in the initial 'Big Bang' of the Universe squeezed matter into tiny regions where the gravitational force took over and created 'mini' black holes. These would be the size of a nucleon, but weighing 10^{15} grams.

While big black holes dominate enormous regions of space, these tiny primordial black holes could affect a region only a few dozen metres across. Estimates of the density of matter in the Universe would be seriously affected by their existence. Some theoreticians have said that the Milky Way could contain up to 10^{23} of these black holes and if so we could expect a few to turn up inside the solar system !

Cosmic thoughts on cosmic rays

Until higher energy colliding beams become available (in the ISABELLE project at Brookhaven, the various Fermilab schemes and the CERN proton-antiproton project) physicists have to rely on cosmic ray phenomena to provide them with glimpses of what happens to hadrons at extremely high collision energies.

Already cosmic rays have been observed whose energies seem to be well in excess of anything even this next generation of colliding beams could provide. These highest energy cosmic particles produce inconsistencies in our present picture of particle interactions and one hope is that the behaviour seen at ISABELLE or other colliding beam projects will make these inconsistencies go away.

The scanty information from cosmic ray interactions is making some physicists hope for great things from the next generation of colliding beam experiments. For example, the number of secondary particles produced from one interaction can far exceed what would be expected by extrapolating experience at laboratory energies and a dearth of neutral mesons shows that the charge distribution of these secondaries can be radically different (see September 1977 issue, page 289).

Unlike beams at accelerators, primary cosmic rays are (presumably) not of a fixed type and, moreover, cannot be observed directly. Terrestrial cosmic ray experiments can only collect the produce of the interactions high up in the atmosphere and the nature of the primary cosmic rays has to be inferred from the observed spectra of these secondaries.

Unusual behaviour by laboratory standards has been seen in events whose primary energy is estimated to be some hundreds of TeV (1 TeV = 1000 GeV) but other phenomena have been recorded whose primary energies appear to extend out into the almost unimaginable 10^8 TeV region.

At these prodigious energies, which make man's present attempts to accelerate particles seem puny, there is enough energy concentrated in one primary particle to light a 40 W light bulb for a second (which normally involves some 10^{18} particles) !

Apart from the major problem of understanding how particles can ever be accelerated to such immense energies, according to our present understanding of particle behaviour it is becoming difficult to explain how such energies persist in a Universe which is not, after all, just made up of sporadic concentrations of matter in an otherwise empty space.

After much theoretical speculation about the possible existence of some permanent electromagnetic radiation filling the whole Universe, it was discovered in 1965 that an isotropic constant radiation does fill space. While being a result of major importance for pure science, this discovery was a spin-off from an investigation of the background radiation problems for satellite communications work.

The wavelength of this radiation is in the 3 mm (microwave) region and corresponds to what would be emitted by a perfect radiator (a 'black body') maintained at a temperature of 2.7°K. As a result, even the furthest regions of outer space are now attributed with this temperature and the microwaves are understood as the vestiges of the intense primordial radiation which existed early in the history of the universe. As the universe expanded, the wavelength of the radiation continually increased due to Doppler shifts, eventually reaching the wavelength we record today.

This all-pervading radiation corresponds to a density of some 550 photons per cubic centimetre, each with a mean energy of some 7×10^{-4} eV, so providing a thin but constant barrier to cosmic particles. When cosmic particles with energies in the 10^8 TeV region meet these feeble photons, the collision energy turns out to be well inside the range explored in the laboratory and should result in the

People and things

formation of particle-antiparticle pairs, in nuclear disintegrations, or in meson production, depending on the nature of the cosmic particles.

All these processes would sap the energy of the primary particles and simple kinematical calculations show that the thresholds where this cosmic ray 'friction' should begin are well below the maximum energies of the primaries estimated from cosmic ray experiments. This makes these extreme energy cosmic rays very difficult to explain according to our present picture. Even if the extreme high energy effects are attributed to neutrinos, with their low affinity for any kind of matter, the problem does not go away.

To get any idea of what happens in the very high collision energies of primary cosmic ray interactions with nuclei high up in the atmosphere and to infer the energy of the primary particles, laboratory experience has to be boldly extrapolated across many orders of magnitude in energy. When results from ISABELLE and other colliding beam experiments become available, these extrapolations will be made with more confidence and the problem might just disappear.

Electron accelerators for nuclear physics

A Study Group, set up to look at the use of electron accelerators in medium energy nuclear physics in the USA, has recommended increased funding for this work and in particular the construction of a new national electron accelerator of 1 to 2 GeV energy.

The Group, headed by Stan Livingston, reported its recommendations to the newly organized DOE-NSF Nuclear Science Advisory Committee, pointing out that the early progress made in the 1950s using electron beams to probe the structure of nuclei has not been followed up. The report contends that the ability of the proposed machine to probe the behaviour of the nucleon-nucleon system at small interaction distances could open up new fields of research for nuclear physicists.

These could include precise measurements of charge and magnetic distributions in nuclei throughout the periodic table, a fuller description of the nucleon-nucleon force through systematic studies on two- and three-particle systems, the study of single particle wave functions and investigations on clustering phenomena in nuclei. Such experiments could supplement present knowledge on nuclear shell models and inter-nucleon potentials. In addition, experimenters would be able to study nuclear interactions under new conditions where meson production plays an important role.

Besides the proposed new accelerator, existing nuclear physics laboratories at MIT, Illinois and Stanford should benefit from increased funding, says the report. In particular, more experience in the use of both conventional and superconducting technologies would be useful before

As Washington interest in the Energy Doubler/Saver has increased, Fermilab has been visited by several prominent Congressmen. Bob Wilson (left) and Ned Goldwasser (right) are explaining a model of the site to Representative Mike McCormack of the House Science/Technology and Public Works/Transportation Committees during a visit in April.

(Photo Fermilab)

the design of the proposed GeV electron machine can be formulated.

New injector for SIN approved

The construction of a new injector cyclotron for the 'meson factory' at the Swiss Institute for Nuclear Research, SIN, has been approved by the Swiss Parliament. The new injector, which will be built at SIN, will provide a proton current of at least 1 mA for injection into the main ring accelerator. It is expected to start operation in 1982. The present external proton channel from the ring, target stations and beam dump, secondary beam lines and shielding will be used for intensities of 400 to 500 μA but higher intensities, which will become available using the new injector, will require some changes. A detailed report on the project will appear in a coming issue of CERN COURIER.

On People

L. Jánossy, Hungarian physicist particularly well known for his contributions in the early days of cosmic ray research, died on 3 March at the age of 66. Professor Jánossy was Professor of Physics at the L. Eötvös University, Scientific Adviser at the Central Research Institute for Physics and member of the Presidium of the Hungarian Academy of Sciences where he served as Vice-President for ten years. He had published over a hundred papers on subjects such as cosmic rays, statistics and relativity. His 1947 monograph on cosmic rays at the Oxford University Press was the first concise account of this field and he also did much to communicate science to the general public.

CERN physicist Brian Couchman was killed in a car accident on 15 April. Brian moved to CERN from Daresbury, where he had participated in the construction of the NINA synchrotron, helped in building the beam transport system of the ISR and then worked in close collaboration with the high energy physicists in the preparation of ISR experiments. He had recently joined the proton-antiproton project after returning from sabbatical leave at SLAC.

Bob Sachs who has been Director of Argonne National Laboratory for the past five years has announced his intention to retire as from 1 October. Professor Sachs wishes to return to academic life. He has successfully guided Argonne through years of change and, in accepting his resignation, J.T. Wilson, the President of the University of Chicago, said that 'his leadership will be hard to replace'.

Kjell Johnsen, renowned leader of the team which built the CERN Intersecting Storage Rings, has accepted an invitation from the Centre national de la recherche scientifique of France and the Max-Planck Gesellschaft zur Förderung der Wissenschaften of the Federal Republic of Germany, to set up an Institute for Radio Astronomy in the Millimetre Range (IRAM). Dr. Johnsen will be seconded from the CERN staff and continues to work temporarily at the CERN site until the location of the Institute is decided.

The American Institute of Physics end-April meeting had a special session to mark the fortieth anniversary of the discovery of nuclear fission with John Wheeler, Lawrence Wilets, Sven Bjornholm and Viki Weisskopf as speakers. There was also a session in memory of Gersh Budker of Novosibirsk with tributes from T.K. Fowler, Roy Schlitters, Fred Mills and Burt Richter. The 1978 Tom W. Bonner Prize for Nuclear Physics was presented during the Meeting to Sergei Polikanov of Dubna and V.M. Strutinsky of Kiev 'for their significant contributions to the discovery and elucidation of isomeric fission'. Also Vernon Hughes of Yale received the 1978 Davisson-Germer Prize 'for his pioneering experiments on muonium and for his measurement of fundamental atomic properties and tests of quantum electrodynamics'.

John Adams, Executive Director General of CERN, received the Honorary Degree of Doctor of Science from the University of Strathclyde on 14 April.

A.F. Gibson, Head of the Laser Division at the Rutherford Laboratory, has been elected Fellow of the Royal Society, FRS, 'for contributions to physics of semi-conductors and for applying them to development of laser detectors and modulators, especially in making possible detection of infra-red laser pulses and in achieving stabilization of CO_2 lasers'.

Leland Haworth, Director of Brookhaven from 1948 to 1961 during which time he produced the world's most condensed accelerator project proposal — a five page letter to the AEC on the building of the Alternating Gradient Synchrotron, has been elected the first-ever Director Emeritus by the Council of Oak Ridge Associated Universities.

J.D. Bjorken, well-known high energy physics theoretician from the Stanford Linear Accelerator Center, was among the five recipients of the E.O. Lawrence Memorial Award for 1977, presented on 27 April.

Maury Tigner, accelerator physicist at Cornell and inventor of the injection technique to be used in the CESR electron positron storage ring, has been appointed Professor in the

1. Hungarian physicist, L. Jánossy, who died in March.

2. Bob Sachs who is to retire as Director of Argonne in October.

Department of Physics and Laboratory of Nuclear Studies at Cornell University.

It was announced at the end of April that the Board of Trustees of the Associated Universities Incorporated, which operates the Brookhaven National Laboratory, has reappointed George Vineyard Director of Brookhaven. Dr. Vineyard has held this post since 1973.

On 24 April, Raymond Davis from Brookhaven received the Cyrus B. Comstock Prize at the Annual Meeting of the National Academy of Sciences in Washington. The Prize, which is given every five years, was awarded 'for his determination of the intensity of neutrino radiation reaching the earth'.

Are you doing the right thing

A recent Harris survey of over 1500 adults in the USA emerged with scientists at the top of the prestige scale among a variety of professional occupations, slightly ahead of doctors. At the bottom of the scale were salesmen, with politicians and journalists not far away!

Making masks at Rutherford

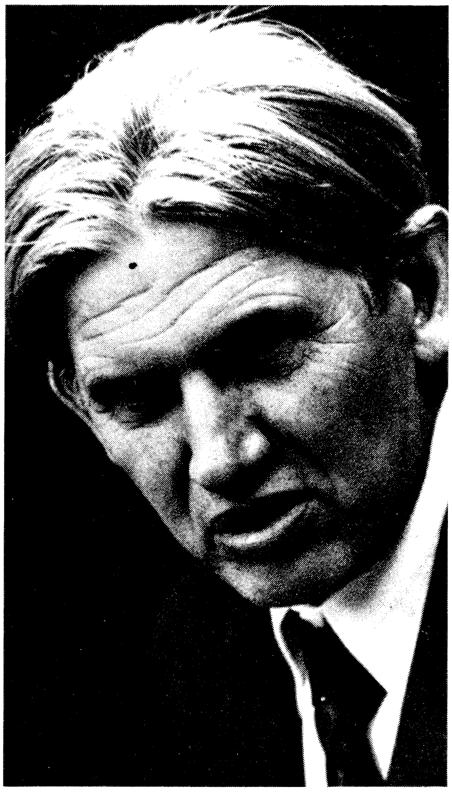
The UK Science Research Council has allocated £ 1.33 M for precision mask making and the fabrication of semiconductor devices. The mask making facility will be at the Rutherford Laboratory using an Electron Beam Lithography (EBL) machine from Cambridge Instruments Company to be delivered at the end of this year. Generating patterns with these computer controlled electron beams makes possible much finer line widths for microelectronic circuits. Components can then be packed with a density as much as two orders of magnitude higher on a single silicon chip. The technique is of great interest to industry and Rutherford will be in collaboration with the Department of Industry, Plessey and GEC. Further technical information is available from R.A. Lawes at the Rutherford Laboratory.

Monitoring airborne cotton

One of the superconductivity projects of Brookhaven National Laboratory is the construction of a length of power transmission line (see November issue, 1974). In the course of this work a problem with oil leaks into the helium has been continually monitored using laser beam scattering from oil particles. The device which does this monitoring reacts to oil levels of a few parts per billion and was developed by Brookhaven and PPM Inc. It works with many types of particle and has found application in cotton mills to monitor airborne cotton dust which can cause the disease known as 'brown lung'. The existing monitors take one reading per eight hour shift and their data needs elaborate processing. The new monitor can take four readings per second and provides the result instantly.

Pop goes the magnet

To recover steel from faulty magnets, Fermilab has applied a brute force technique to prise the magnets apart. Rather than burning off the 'glue' holding the magnet blocks together in a furnace, the magnets are immersed in liquid nitrogen and a hefty current is passed through the coils. The steel core stays cold via the nitrogen while the copper coils heat up until the mechanical stresses become too great and the magnet pops open. Total cost is around $70 per magnet (almost all of it for the nitrogen which is boiled off) which is much lower than conventional techniques.



1.

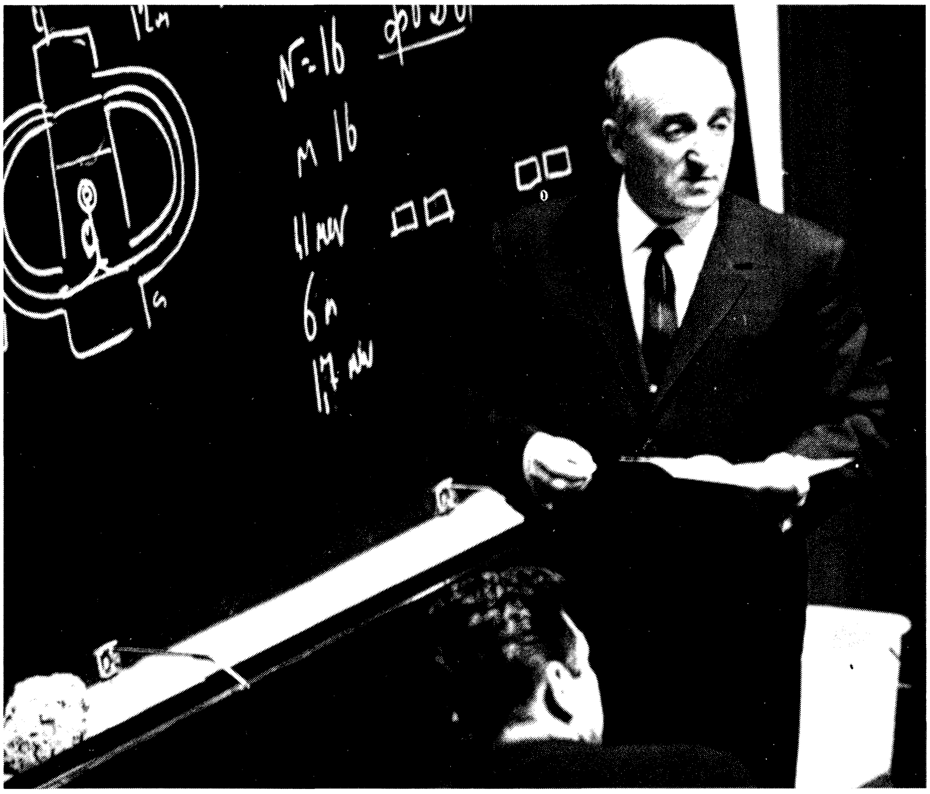
2.

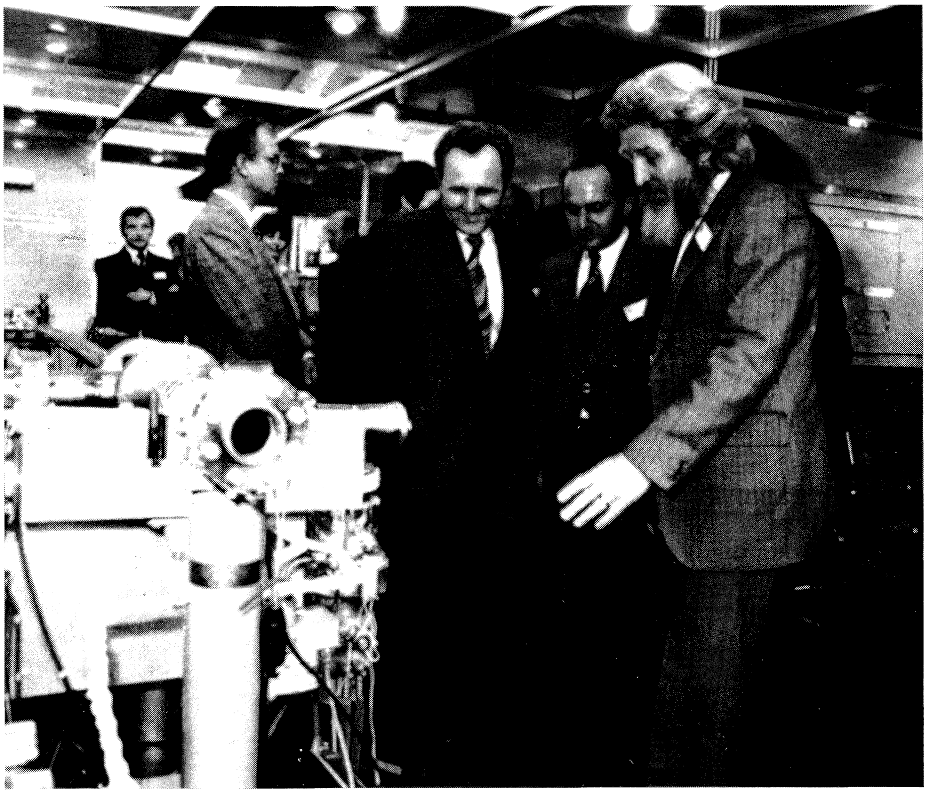
The late Gersh Budker photographed during a seminar at CERN. Tribute was paid to his memory in his Institute in Novosibirsk at the end of April.

(Photo CERN 356.4.67)

CERN had a very successful stand at the Hanover Fair from 19-27 April presenting vacuum technology, particularly as developed for the Intersecting Storage Rings. Among the many visitors to the stand was Erwin Stahl (third from right) the German Parliamentary Secretary for Research and Technology. He is photographed here in conversation with Erhard Fischer (right) head of the ISR vacuum group and Eric Lohrmann (second from right) CERN Directorate Member.

(Photo Hans Jurgen Fratzer)





Tribute to Gersh Budker

On 25-27 April the Novosibirsk Institute of Nuclear Physics held a Budker Memorial Seminar in honour of the former Director, Gersh Budker, who died in July of last year. The Institute, which was very much Budker's creation, had celebrated the twentieth anniversary of its foundation the day before, 24 April.

Talks were given on many of the subjects in which Gersh Budker had had a great interest and had played a leading role. Particularly topical at the moment were some new results on electron cooling of proton beams. The Novosibirsk team has achieved cooling of a 1.5 MeV proton beam (the injection energy into the cooling ring NAP-M) with an electron current of 2 mA. The cooling time was 0.2 s which scales with energy as predicted (with beta squared) compared to the previous tests at 65 MeV.

It was recalled during the Seminar that Budker's original scheme for electron cooling involved high energy application with a small electron storage ring. This was not pursued and only low energy tests with currents from electron guns have been made so far. However, the high energy idea has now been resurrected by Carlo Rubbia with the realization that it can be applied to pre-cooled beams in connection with the proton-antiproton projects (see April issue, page 114).

Accelerators and medicine in Japan

The Japanese Radiological Society is promoting an interdisciplinary research project, supported by a national grant, on the 'biomedical use of accelerators'. Accelerator physicists and doctors from throughout Japan are participating in the project. It was brought to our attention by M. Akisada who is Chairman of the Department of Radiology at the University of Tsukuba.

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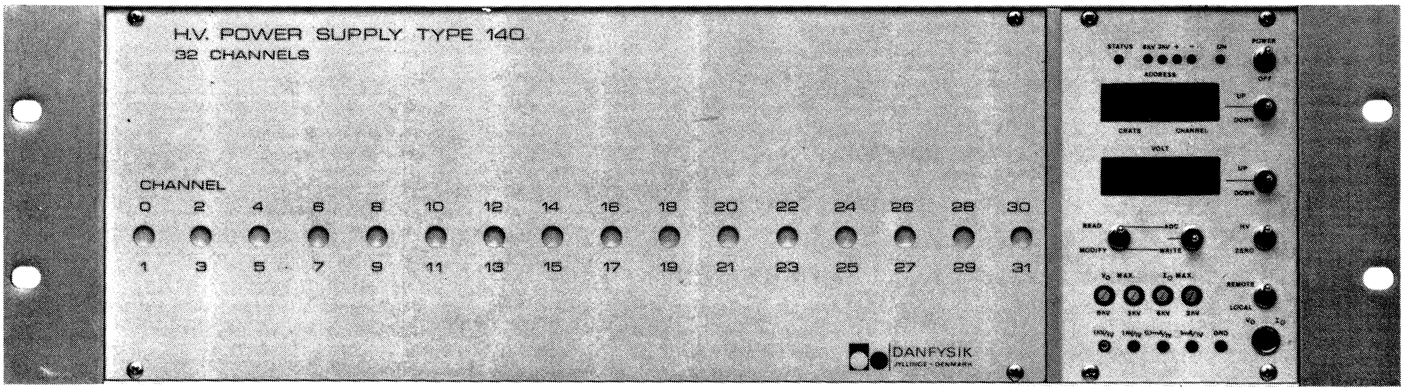

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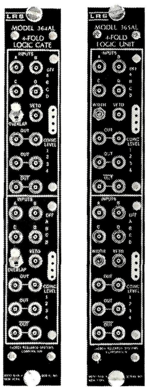

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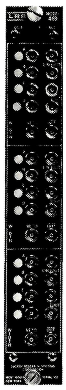

Triple 4-Fold Coincidence
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Quad 2-Fold Logic Unit
MODEL 622
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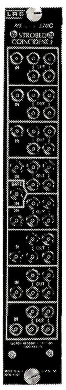

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Accepts 8 NIM inputs and a latching strobe to record the status of a set of detectors. Coincidence resolution <1.8 nsec. Useful for multitrigger configurations. 125 MHz operation.

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MODEL 380A
Accepts up to 32 NIM inputs. Supplies a NIM logic pulse when N inputs fire simultaneously ($1 \leq N \leq 6$). N is switch-selectable. A $>N$ output is also supplied. Larger multiplicity and greater than 32 inputs are achievable by using the summing output. Module simplifies straightforward hodoscope logic.

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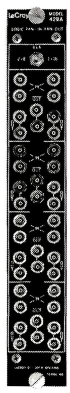

Quad Mixed Logic Fan-In/Fan-Out
MODEL 429A
Each of the 4 independent channels logically ORs 4 NIM inputs. All inputs respond to both NIM and TTL signal levels. Provides three -32 mA NIM output pairs, two normal and one complementary. Contains provision for channel mixing 2×8, 4×4 or 1×16. Direct-coupling throughout means no duty cycle effects. Unique design keeps power requirements within NIM specs.

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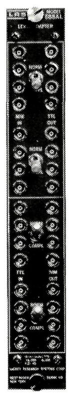

Level Adapter
MODEL 688AL
Solves the problem of mixing NIM and TTL logic signals. Converts 8 channels of NIM to TTL and 8 channels of TTL to NIM.

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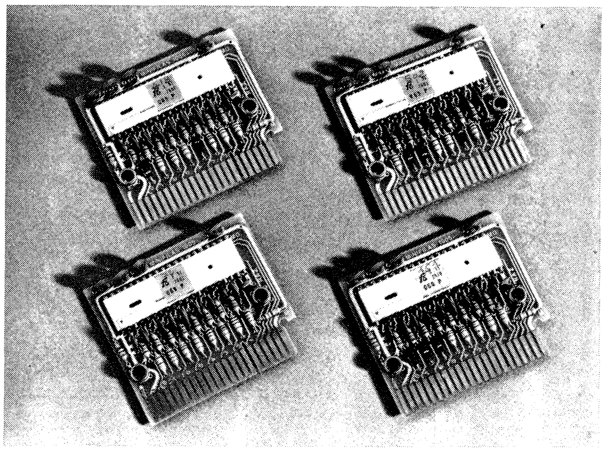

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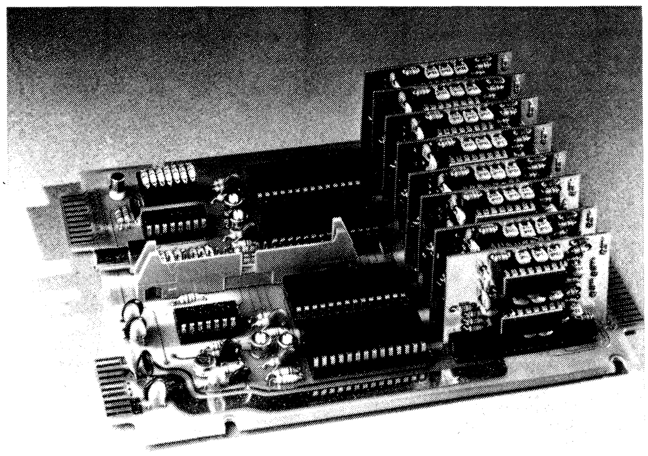

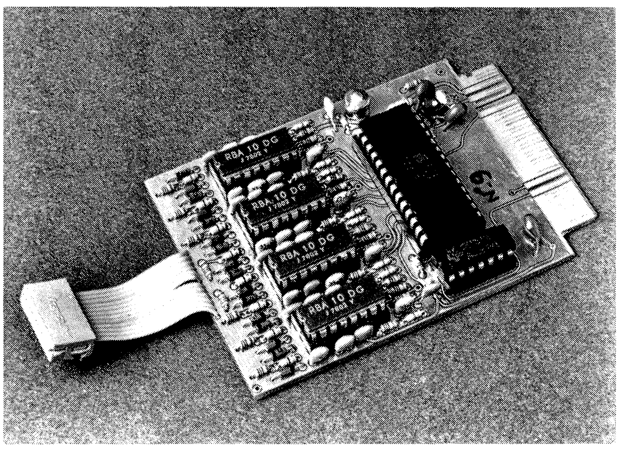

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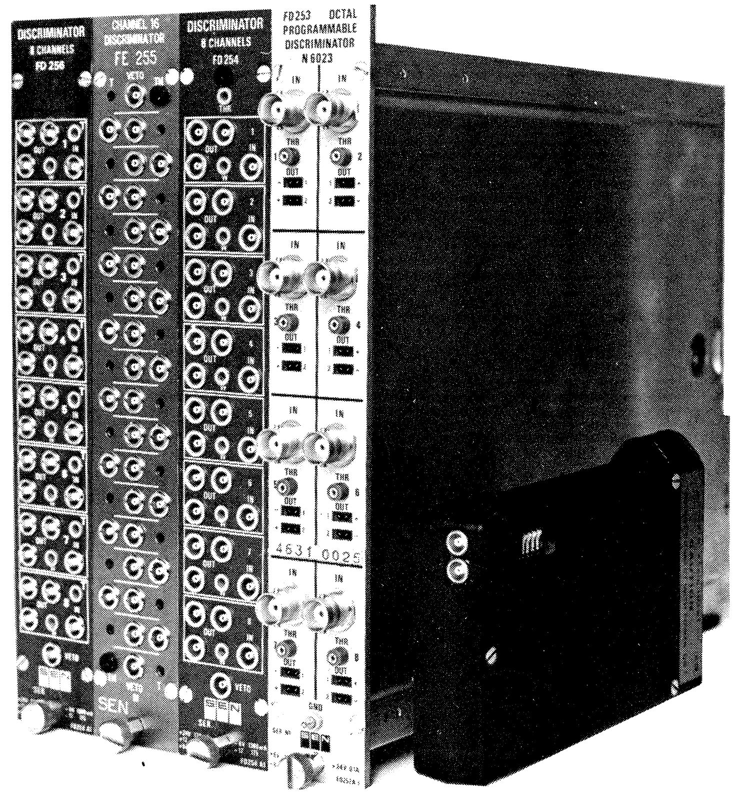

TYPE	FD 253	FD 254	FD 255	FD 256
Nb of channels	8	8	16	8
Updating	yes	yes	yes	yes
Threshold (mV)	−30 to −540 computer controlled*	−8 to −1000 screw driver adj. common to 8 ch.	−8 to −1000 screw driver adj. common to 8 ch.	−8 to −1000 screw driver adj.
Output width (ns)	5 to 35 computer controlled*	<5 to >40	<5 to >40	<5 to >40
Nb of outputs	2	3	1	3
Fast veto	no	yes	yes	yes
Typical rate (Mz)	100	100	100	100
Double pulse resolution (ns)	10	⩽10	⩽10	⩽10
Time slewing (ns)	⩽1	⩽1	⩽1	⩽1
Input connector	BNC	Lemo	Lemo	Lemo
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Input-output delay (ns)	19 to 34 computer controlled*	⩽20	⩽20	⩽20
Output level	MecL	NIM	NIM	NIM

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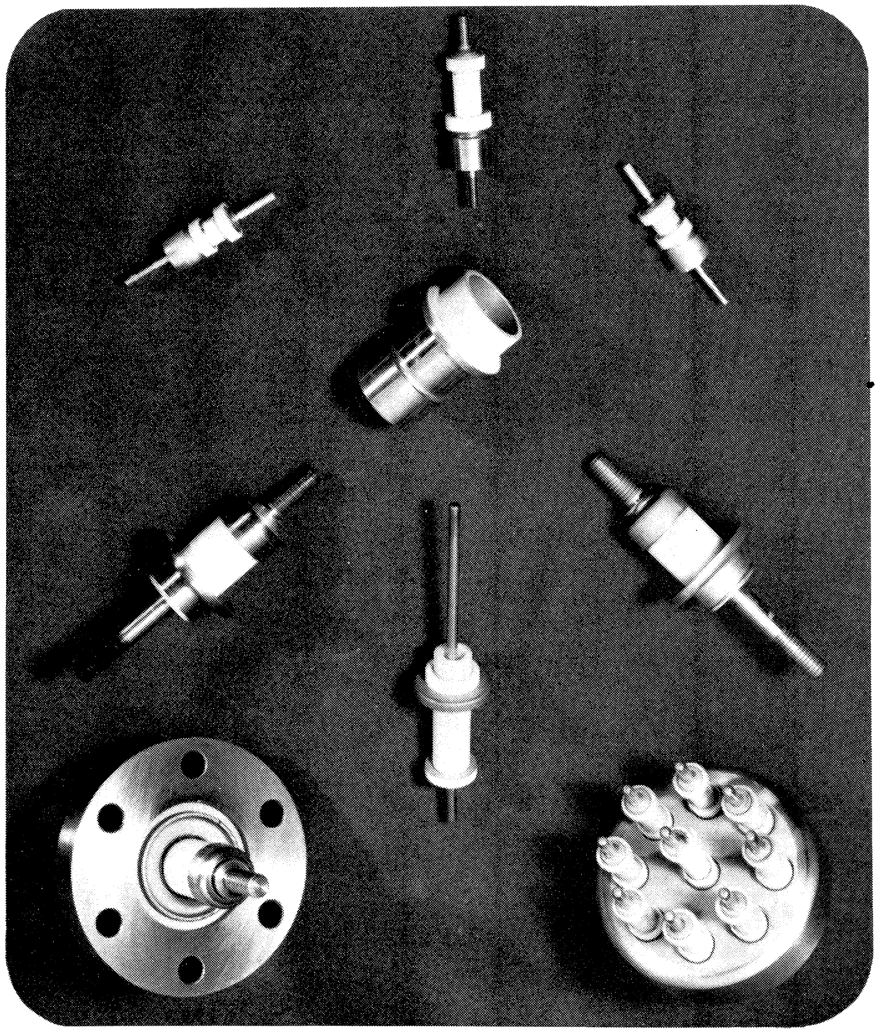

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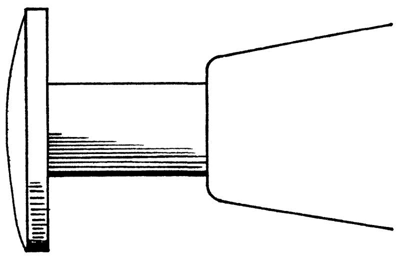

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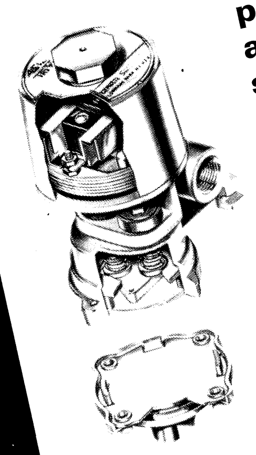

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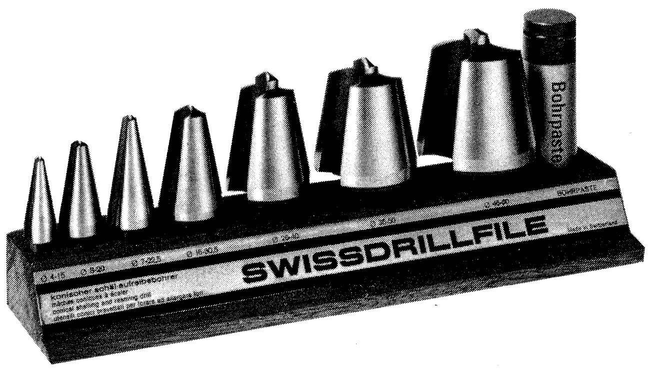

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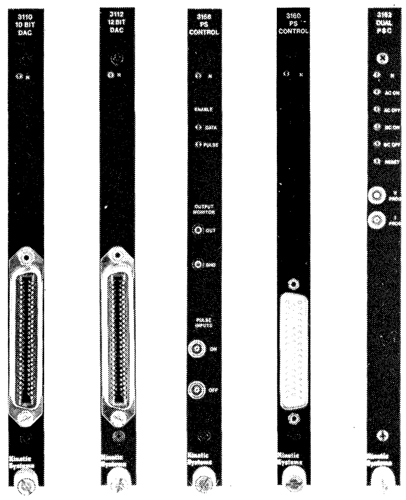

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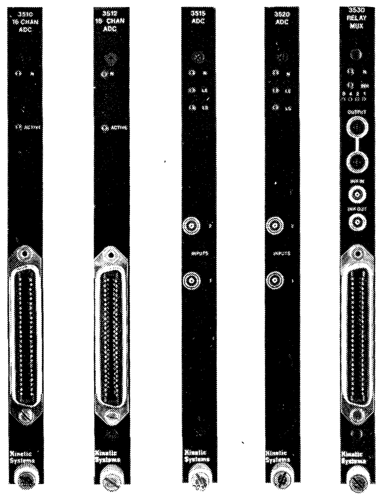
CAMAC modules handle a wealth of analog I/O



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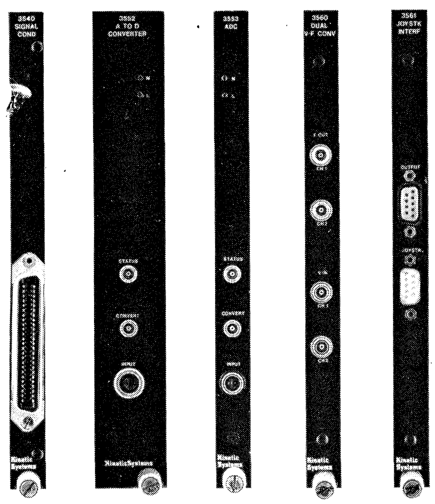

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ANALOG OUTPUT

These modules provide one or more precision voltage outputs for use in such analog control and monitoring situations as driving X-Y recorders, driving panel meters, and programming power supplies. Power supply controllers also provide output control signals and binary status input.

3110 8-Channel, 10-Bit D/A Converter
3112 8-Channel, 12-Bit D/A Converter
3158 Power Supply Controller
12-bit D/A converter, 4 digital output control signals, 8 status input signals
3160 Power Supply Controller
contains an additional output control signal
3162 Power Supply Controller
features two 12-bit D/A converters

ANALOG INPUT

These modules provide the ability to monitor analog parameters. Included are multiplexing, signal conditioning, and various types of single and dual A/D converters.

3510 16-Channel Scanning A/D Converter (11 bits)
3512 16-Channel Scanning A/D Converter (12 bits)
3515 10-Bit A/D Converter
3520 12-Bit A/D Converter
3530 15-Channel Relay Multiplexer
used alone or to expand the 3552 or 3553 to multi-channel applications
3540 16-Channel Signal Conditioner
external amplifiers measure low-level signals from strain gauges, thermocouples, or other transducers. Can be used with the 3510 or 3512
3552 12-Bit A/D Converter
3553 12-Bit A/D Converter
3560 Dual V-F Converter
3561 Joystick Interface

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